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NOVA-2 - A Digital Computer Program for Analyzing Nuclear Overpressure Effects on Aircraft. Part 2. Computer Program

Kaman AviDyne

August 1976

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NOVA-2 — A DIGITAL COMPUTER PROGRAM FOR ANALYZING NUCLEAR OVERPRESSURE EFFECTS ON AIRCRAFT

Part 2
Computer Program

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August 1976

Final Report

Approved for public release; distribution unlimited.

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base, NM 87117

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18. SUPPLEMENTARY NOTES

This report consists of two parts. Part 1, Theory, includes the front matter, Sections I through V, pages 1 to 196. Part 2, Computer Program, includes Section VI and the references, pages 197 to 348.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aircraft aerodynamic loading
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Overpressure effects
Structural response of beam and panel elements

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

NOVA-2 (Nuclear Overpressure Vulnerability Analysis, Version 2) is an updated version of NOVA, a FORTRAN-IV digital computer program for calculating the response of individual structural elements of aircraft, such as stringers, frames and panels, exposed to the transient pressure loading associated with the blast wave from a nuclear explosion. The updated version extends the capability of NOVA to analyze rib elements, frames with variable cross section, and offers a choice of clamped, simply supported or free edge boundary (over)

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ABSTRACT (cont'd)

conditions. For inelastic structural response, a much improved elastic plastic model for material behavior is provided. Also added to NOVA is the REFRA near-ground reflections model for blast waves. The program still provides the overall capability to analyze multilayered beam and panel elements exposed to a steady-state subsonic or supersonic aerodynamic preload, followed by a dynamic blast wave. A critical slant range is automatically determined in an iteration where damage criteria (specified on a probabilistic basis) are compared with the structural response.

SECTION VI
PROGRAM DESCRIPTION AND OPERATION

The NOVA computer program can be divided into three distinct sets of routines, identified as NOVA, DEPROB and DEPROP. DEPROB is responsible for the structural response of beam elements, DEPROP is similarly responsible for panel elements, and NOVA contains the aerodynamics, the blast routines, the vulnerability iteration routines, and controls the program as a whole. The specific routines associated with each program are listed in table 15. A description of each routine follows in subsection 6.1 and 6.2, along with the complete instructions for the operation of the NOVA computer code in subsections 6.3 and 6.4.

6.1 DESCRIPTION OF ROUTINES

Table 15 lists the 103 routines which make up NOVA, most of which are described in this section. A brief description of the purpose is given, followed by a list of routines it references, and which routines reference it. In addition, flow diagrams of the major subprograms are given. It should be noted that routines referenced by both DEPROB and DEPROP are included in the NOVA group of routines, since such routines belong, in a sense, to the program as a whole rather than to either structural code.

Table 16 lists all of the labeled common blocks in the program, the length of each common, and the subprograms which use each common block. The underlined subprogram names in table 16 indicate the subprogram which "owns" it in a recommended segmentation procedure to be discussed in section 6.4.

TABLE 15. LIST OF SUBPROGRAMS

NOVA		DEPROP	DEPROB
NOVA	WFDZR	DEPROP	DEPROB
BLOCK	WELL	BOLT	COMP1
IODUM	WFPRMT	DSET1	COMP2
SEC	WFVZR	DSET2	COMSET
NIN	WFVRMT	DSET3	CYCLE
NEWSL	AIR	DERV2	DAB
NOVSUM	WFPKOP	DTSTEP	DEFORM
RITC	REFRA	HIM	DPUR
RITER	OPT1	LEGEND	EQUIL[illegible]
CSETUP	OPT2	LIST1	EQUILX
INTP	OPT3	LIST2	FB
PINIT	ADVANC	RELAXP	FBCTL
SOLVE	BISH	SIGMA	FBSET
BLAST	READ		FINAL
XBLAST	POSTAP		FSOL
HYDRA	SKIP		PRINT1
IOPT1	FPRES		READ1
IOPT2	INTSLO		RESD
IOPT3	PFUSE		RESET
ATMOS	PJUMP		RLAXB
MATM62	POSTW1		RLAXF
SHOCK	POSTW2		SLAY
TPINT	POSTW3		STRESS
INT1	POSTW4		STRESX
INT2	POSTW5		STRN1
WFZR	POSTW6		STRN2
WFPKOD	POSTW7		STSET
WFPR	PRESS		TSTEP
WFPKV	PREW		VCS
WFDRMT	SETW		
	WPRES		

TABLE 16. COMMON BLOCKS AND SUBPROGRAMS USING THEM

Common Block	Length (Decimal)	Subprograms
CNOVA	142	NOVA*, NIN, NEWSL, NOVSUM, RITC, CSETUP, BLAST, XBLAST, PINIT, FPRES, PRESS, PREW, WPRES, DEPROP, DSET1, DSET2, DSET3, DERV2, DTSTEP, LIST1, LIST2, SIGMA, DEPROB, COMP1, COMP2, COMSET, CYCLE, DEFORM, EQUILP, EQUILX, FB, FINAL, PRINT1, READ1, STRESS, TSTEP.
DNOVA	2858	NOVA, BLOCK, NIN, NEWSL, NOVSUM, RITC, BLAST, XBLAST, PINIT, FPRES, POSTW1, POSTW2, POSTW3, POSTW4, PCSTW5, POSTW6, POSTW7, PRESS, PREW, SETW, WPRES
CTLX	2	NOVA, BLAST, REFRA, FPRES, WPRES
CONSTC	15	HYDRA, IOPT1, IOPT2, IOPT3
SCALEC	5	HYDRA, IOPT1, IOPT2, IOPT3, SHOCK
WFRT	13	SHOCK, WFPKOD, WFPR, WFPKV, WFDRMT, WELL, WFPRMT, WFVRMT
REFRAC	7495	REFRA, OPT1, OPT2, ADVANC, READ, SKIP
PW1	23	POSTW1, POSTW2, POSTW3, POSTW4, POSTW5, POSTW6, POSTW7, SETW, WPRES
CBLK1	82	DEPROP, BOLT, DSET1, DSET2, DSET3, DERV2, DTSTEP, LEGEND, LIST1, LIST2, SIGMA
CBLK2	1990	DEPROP, BOLT, DSET1, DSET2, DSET3, DERV2, DTSTEP

*Underlined routine owns that common block in segmentation setup.

Table 16. (Concluded)

CBLK3	12	DEPROP, DSET1, DSET2, DSET3, DERV2, LEGEND, SIGMA
CBLK4	226	DEPROP, DSET1, DSET2, DSET3, DERV2, SIGMA
CBLK5	393	DEPROP, DSET1, DSET2, DSET3
CBLK6	12355	DEPROP, DSET1, DSET2, DSET3, DERV2, LIST1, LIST2, SIGMA
CBLK7	12	DEPROP, DSET1, DSET2, DSET3, LIST2, SIGMA
CBLK8	50	DEPROP, DSET1, DSET2, DSET3, DERV2
CBLK9	128	DEPROP, DSET1, DSET2, DSET3, LIST1, LIST2
CBLK10	5776	DEPROP, DSET1, DSET2, DSET3, DERV2, LIST1, LIST2
CBLK11	12	DEPROP, DSET1, DSET2, DSET3, DERV2
CBLK12	6150	RELAXP
CBLK13	9	DEPROP, DSET1, DSET2, DSET3, DTSTEP
CBLANK	30056	SIGMA
CHIM	76	HIM
BLK2	12266	DEPROB, COMP1, COMP2, COMSET, CYCLE, DAB, DEFORM, DPUR, EQUILP, EQUILX, FB, FBCTL, FBSET, FINAL, FSOL, PRINT1 READ1, RESD, RESET, SLAY, STRESS, STRESX, STRN1, STRN2, STSET, DTSTEP, VCS
BLK3	466	DAB, DEFORM, DPUR, FSOL, RESD, RESET, STSET
BLK4	7216	RLAXB
BLK5	21	RLAXF
BLK6	2269	COMP1, COMP2, COMSET, DEFORM, FB, FBSET, PRINT1, STRESS, STRN1, STRN2

6.1.1 NOVA

The NOVA routine is the master routine which controls the logic of the overall program. It contains the subroutines for predicting the aerodynamic flight loads, the blast pressure loads that are applied to the lifting surfaces and fuselage during subsonic and supersonic flight, and the iterative technique for determining the slant range at which a structural element incurs damage which has been specified on a probabilistic basis.

NOVA reads the input data associated with specific aircraft, weapon, and structural element parameters which are outlined in paragraph 6.3.1. Figures 66 and 67 present flow diagrams for NOVA and for subroutine PINIT, respectively.

Fourteen of the subprograms comprising the 1-KT free-air blast model are not described in detail here as they are the product of AFWL (refs. 2 and 3). Subroutines HYDRA, IOPT1, IOPT2 and ATMOS were written to make the model consistent with earlier versions of HYDRA using the data tape. The only changes to the AFWL functions were: 1) the suppression of the two-dimensional fireball effect, 2) the lengthening of common block WMRT in certain routines to make them all equal length, and 3) the addition of an error message in function WFPKOD.

Similarly, the REFRA routines are not described in detail due to the existing documentation (ref. 7). The ground reflection model is a self-contained package, the only required change being the addition of common block CTLX.

The following is a brief description of all other routines belonging to the NOVA group (listed alphabetically), including their relationship with other programs:

<u>NOVA</u>

Main program, exercises entire vulnerability code.
Calls ATMOS, BLAST, BLOCK, DEPROB, DEPROP, NEWSL, NIN, NOVSUM, PINIT, RITC.

ATMOS

Calculates ambient atmospheric properties as a function of altitude.
Calls MATM62.
Called by NOVA, REFRA, XBLAST.

BLAST

Calls the appropriate blast package, depending on ground reflection option.
Calls REFRA, XBLAST.
Called by NOVA, FPRES, NOVSUM, WPRES.

BLOCK

Sets up nominal direction cosines for 21 burst orientations.
Called by NOVA.

CSETUP

Sets up constants related to damage criteria for use by DEPROB and DEPROP in determining ratio of maximum response to critical levels of response.
Calls INT1.
Called by DEPROB, DEPROP.

FPRES

Calculates times and associated flow conditions for fuselage points.
Calls BLAST, PFUSE, PJUMP.
Called by PINIT.

HYDRA

Responsible for obtaining free-air blast characteristics.
Calls IOPT1, IOPT2, IOPT3, MATM62.
Called by OPT1, OPT2, REFRA, XBLAST.

INTP

One-dimensional interpolation routine for time-pressure tables, where time is always increasing.
Called by PRESS.

INTSLO

Performs one-dimensional interpolation and also calculates slope.
Called by WPRES.

INT1

Performs one-dimensional interpolation.
Called by CSETUP, XBLAST.

INT2

Performs two-dimensional interpolation.
Called by XBLAST.

IODUM

Dummy routine whose sole purpose is to cause the loading of all IO system routines in the root level of segmentation setup. Necessary because of current problem with loader.
Not referenced.

IOPT1

Finds free-air blast characteristics given time and distance from burst.
Calls SHOCK.
Called by HYDRA.

IOPT2

Finds incident shock wave position given time from burst.
Calls WPKOP, WFPR.
Called by HYDRA.

IOPT3

Finds time of arrival of incident shock wave given distance from burst.
Calls WFPKOP, WFPR.
Called by HYDRA.

NIN

Reads basic aircraft data and prints out description.
Called by NOVA.

NEWSL

Reads aircraft data associated with each structural element and prints out description.
Called by NOVA.

NOVSUM

Prints summary of results of entire NOVA run and selects critical element for each orientation.
Called by NOVA.

PFUSE

Calculates steady-state pressure on fuselage.
Called by FPRES.

PINIT

Assembles pressure-time table and provides initial pressure for DEPROB or DEPROP.
Calls FPRES, WPRES.
Called by NOVA.

PJUMP

Calculates jump in fuselage pressure at shock arrival.
Called by FPRES.

POSTW1, POSTW2, POSTW3, POSTW4, POSTW5, POSTW6, POSTW7

Determine the post-blast aerodynamic loading on a lifting surface for seven different cases. The number in the subroutine name corresponds to NCASE, as determined in subroutine SETW. Called by WPRES.

PRESS

Interpolates pressure for DEPROB or DEPROP.
Calls INTP.
Called by CYCLE (DEPROB), DERV2(DEPROP).

PREW

Determines preblast aerodynamic loading on a lifting surface.
Called by WPRES.

REFRA

Determines blast characteristics, with or without near-ground reflection effects, as provided on data tape, file TAPE10.
Calls ATMOS, HYDRA, OPT1, OPT2, OPT3.
Called by BLAST.

RITC

Controls range iteration as a function of structural response. Iteration is either along slant range or constrained to constant altitude.
Calls RITER.
Called by NOVA.

RITER

Calculates new trial range, making use of up to three previous trials, if possible. Checks to see if criterion is decreasing as range increases, and determines if iteration has converged on an acceptable range.
Called by RITC.

SEC

Finds elapsed CP time.
Calls system routine SECOND.
Called by COMSET(DEPROB), FINAL(DEPROB), DEPROP.

SETW

Determines which post-blast subroutine is to calculate the aerodynamic loading. Sets up several quantities which are independent of time and position.
Called by WPRES.

SOLVE

Solves a set of simultaneous linear algebraic equations.
Called by RLAXB(DEPROB), RELAXP(DEPROP).

TPINT

Solves for intersection of shock wave with triple point path.
Called by XBLAST.

WPRES

Calculates times and associated flow conditions for wing (lifting surface) points.
Calls INTSLO, POSTW1, POSTW2, POSTW3, POSTW4, POSTW5, POSTW6, POSTW7, PREW, SETW, XBLAST.
Called by PINIT.

XBLAST

Calculates blast characteristics using analytical curve fit for near-ground reflection effects.
Calls ATMOS, HYDRA, INT1, INT2.
Called by BLAST.

6.1.2 DEPROB

The DEPROB portion of the program contains the routines for calculating static and dynamic, elastic or inelastic response of aircraft structures such as stringers, longerons, frames, ribs, and conical or cylindrical shell sections which can be represented by a ring. The method can also be applied in certain circumstances to panels with sufficiently high aspect ratio.

DEPROB reads the input data described in section 6.3.2. Flow diagrams of the major routines are presented in figures 68-71, and other descriptive information is provided below.

DEPROB

Executes the static and dynamic beam solutions.
Calls COMP1, COMP2, COMSET, CSETUP(NOVA), CYCLE, DEFORM, FBSET, FINAL, PRINT1, READ1, STRN2, TSTEP.
Called by NOVA.

COMP1

Creates idealized model of cross section and stress-strain model.
Calls SLAY, VCS.
Called by DEPROB.

COMP2

Sets up spanwise model of beam and locates origin at center of gravity.
Writes major variables to file TAPE1.
Calls STRN1.
Called by DEPROB.

COMSET

Sets major program variables to values corresponding to static results.
Reads from file TAPE1.
Called by DEPROB.

CYCLE

Executes dynamic response, and performs numerical temporal integration.
Calls EQUILP, FB, PRESS (NOVA), PRINT1, STRESS, STRN2.
Called by DEPROB.

DAB

Calculates variables after a trial has been completed in iterative static solution process.
Called by DEFORM.

DEFORM

Executes static analysis and writes major variables on file TAPE1.
Calls DAB, DPUR, EQUILX, FBCTL, FSOL, PRINT1, RESD, RESET, RLAXB, SEC, STRESS, STRESX, STRN2, STSET.
Called by DEPROB.

DPUR

Calculates variables after each perturbation in the static solution process.
Called by DEFORM.

EQUILP

Calculates external forces and accelerations during dynamic response.
Called by CYCLE.

EQUILX

Same as EQUILP, except is appropriate for the static solution.
Called by DEFORM.

FB

Determines conditions near clamped edge boundaries through an iterative procedure.
Calls RLAXF.
Called by CYCLE, FBCTL.

FBCTL

Controls calls to FB during static solution process.
Calls FB, FBSET.
Called by DEFORM.

FBSET

Initializes variables for FB solution.
Called by DEPROB, FBCTL.

FINAL

Compares accumulated maximum response values with criteria at end of dynamic response, and prints results.
Calls PRINT1, SEC.
Called by DEPROB.

FSOL

Assembles variables corresponding to final static solution.
Called by DEFORM.

PRINT1

Prints most of the DEPROB output.
Called by DEPROB, CYCLE, DEFORM, FINAL.

READ1

Reads input data for DEPROB and prints out description of data.
Called by DEPROB.

RESD

Computes residues in the iterative static solution process.
Called by DEFORM.

RESET

Resets variables during static solution process.
Called by DEFORM.

RLAXB

Solves simultaneous nonlinear equations associated with static solution using relaxation procedure. Checks to see if solution is converging.
Calls SOLVE (NOVA).
Called by DEFORM.

RLAXF

Solves simultaneous equations associated with clamped edge condition and checks to see if solution is converging.
Called by FB.

SLAY

Sets up mechanical sublayer stress strain model.
Called by COMP1.

STRESS

Determines strains, stresses and internal moments and forces during dynamic response.
Called by CYCLE, DEFORM.

STRESX

Same as STRESS, except is appropriate for the static solution.
Called by DEFORM.

STRN1

Calculates initial lengths and angles corresponding to spanwise shape.
Called by COMP2.

STRN2

Calculates lengths and angles in the bar-mass representation for dynamic response.
Called by DEPROB, CYCLE, DEFORM.

STSET

Sets up constants for static solution.
Called by DEFORM.

TSTEP

Calculates an integration time step small enough to avoid numerical instabilities.
Called by DEPROB.

VCS

Sets up geometrical variables for beams of variable cross section.
Called by COMP1.

6.1.3 DEPROP

The DEPROP routines provide the static and dynamic, elastic or inelastic response of aircraft skin panels, canopies, and radomes that can be approximated by a cylindrical panel. The elastic option applies to single and multilayered panels of isotropic or orthotropic material, and the elastic-plastic options apply to single layer (or honeycomb) panels of isotropic material.

Flow diagrams of the major routines are presented in figures 72-74. It should be noted that subroutine SIGMA is only needed for the elastic-plastic option.

The following is a description of the routines belonging to DEPROP:

DEPROP

Executes the static and dynamic panel solutions.
Calls CSETUP(NOVA), DERV2, DSET1, DSET2, DSET3, HIM, LIST1, LIST2, RELAXP, SEC.
Called by NOVA.

BOLT

Sets up W mode shapes for boundary conditions selected.
Called by DSET1.

DERV2

Computes strains, displacements, and accelerations in the main integration loop.
Calls LIST1, LIST2, PRESS, SIGMA.
Called by DEPROP.

DTSTEP

Computes an integration time step small enough to avoid numerical instabilities.
Called by DSET2.

DSET1

Reads DEPROP input data and calculates constants.
Called by DEPROP.

DSET2

Calculates constants used in DEPROP.
Calls LEGEND, DTSTEP.
Called by DEPROP.

DSET3

Calculates additional constants and writes out a description of input data.
Calls BOLT.
Called by DEPROP.

HIM

Numerical timewise integration routine.
Called by DEPROP.

LEGEND

Sets up constants for Gaussian integration through the thickness for an elastic-plastic solution.

Called by DSET2.

LIST1

Output routine for the elastic-only option. Maximum response values are accumulated and compared with allowables.
Called by DEPROP, DERV2.

LIST2

Output routine for the elastic-plastic option. Maximum response values are accumulated and compared with allowables.
Called by DEPROP, DERV2.

RELAXP

Solves simultaneous nonlinear equations representing preblast conditions using a relaxation procedure.
Calls SOLVE(NOVA).
Called by DEPROP.

SIGMA

Computes stresses in the main integration loop for the elastic-plastic option. Is not needed for the elastic-only option.
Called by DERV2.

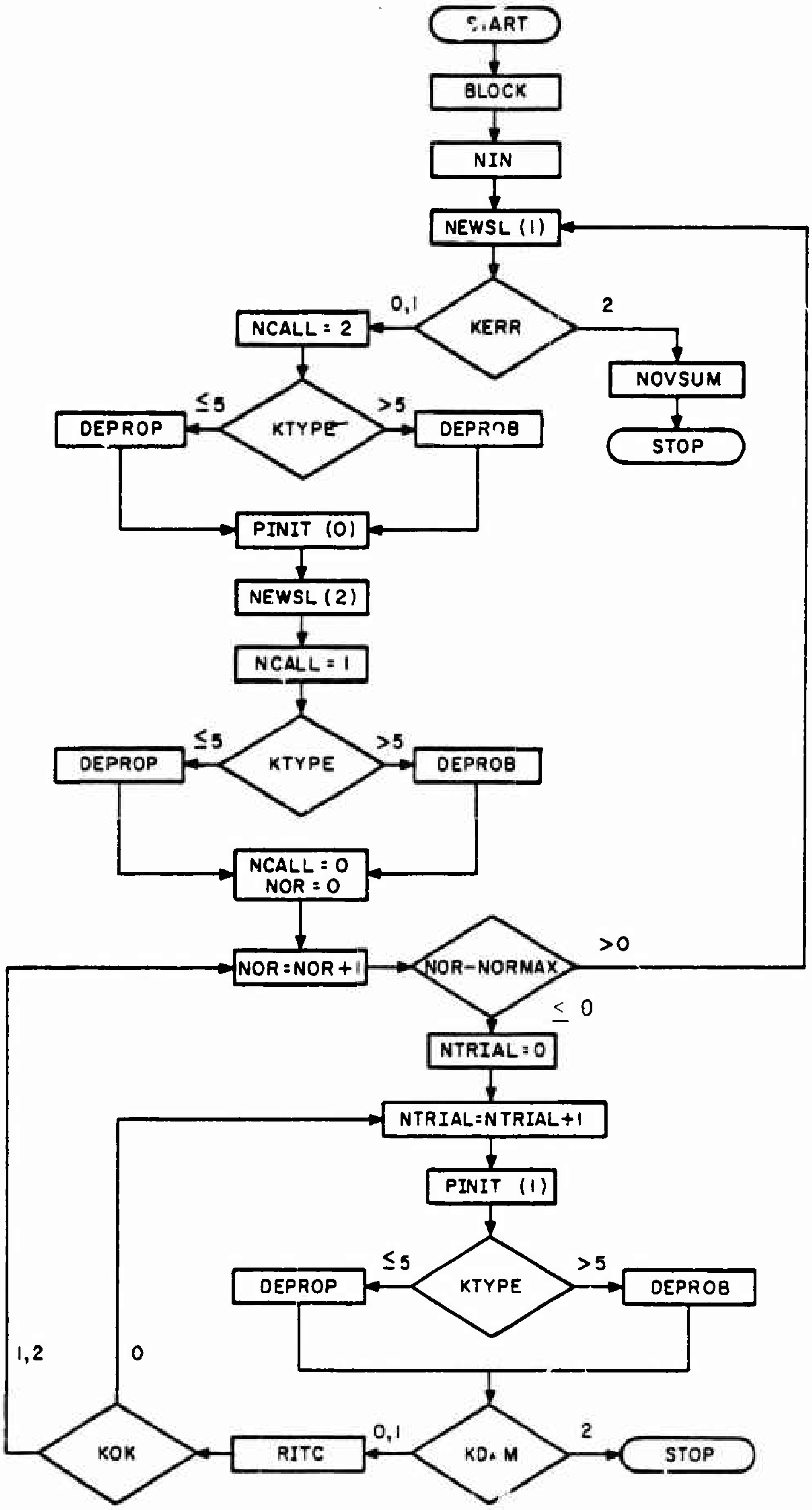


Figure 66. Program NOVA Flow Diagram

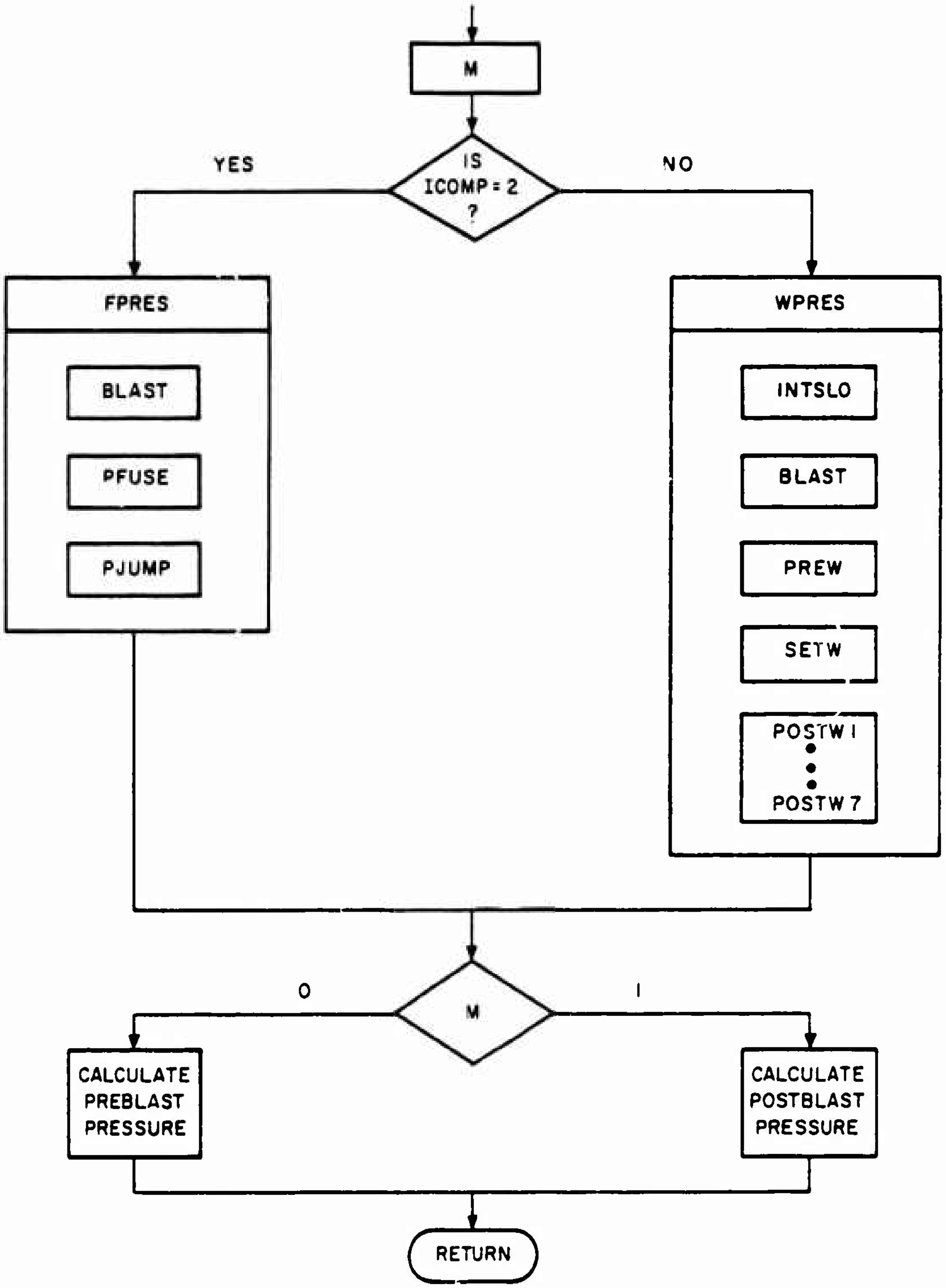


Figure 67. Subroutine PINIT Flow Diagram

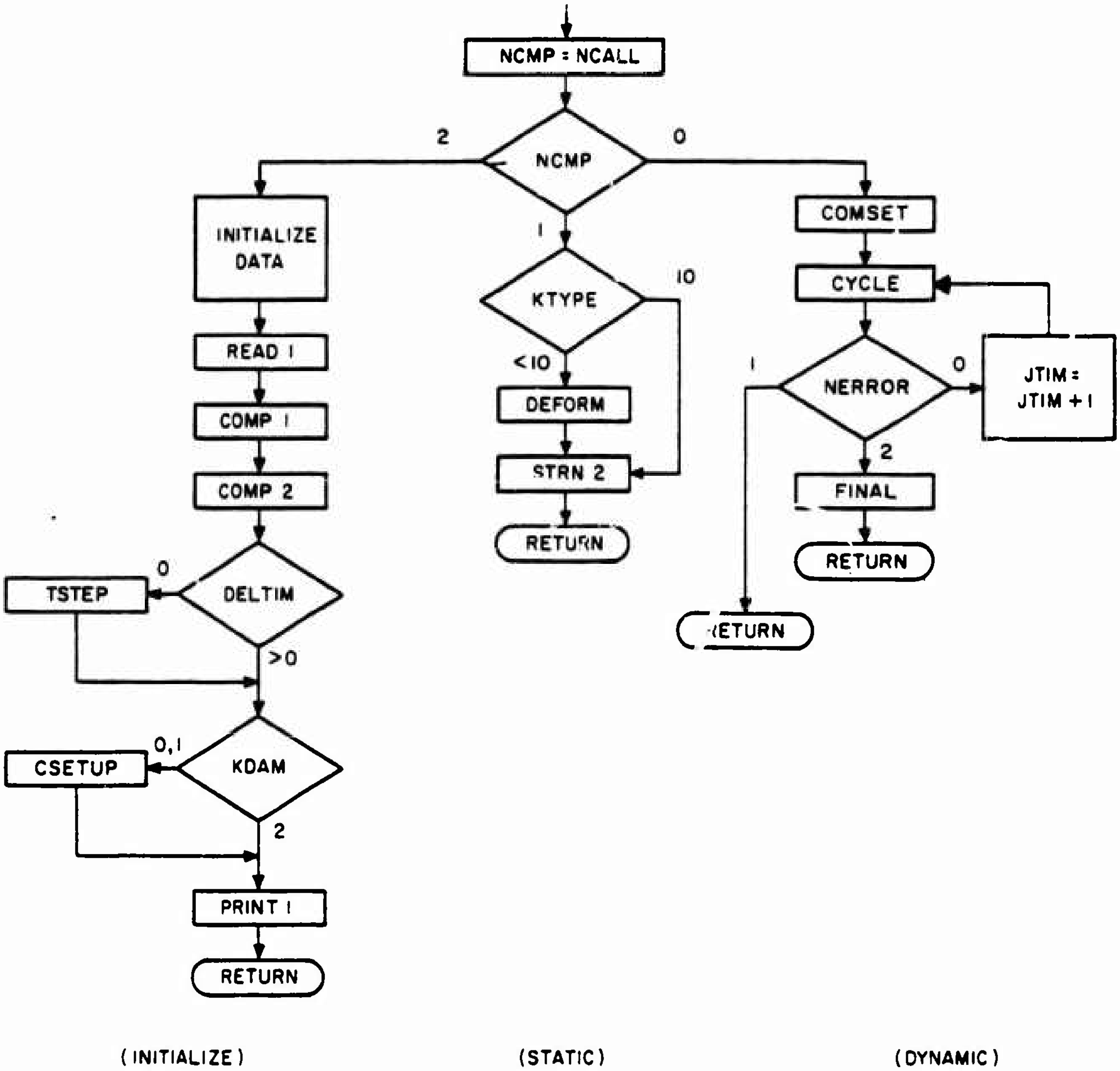


Figure 68. Subroutine DEPROB Flow Diagram

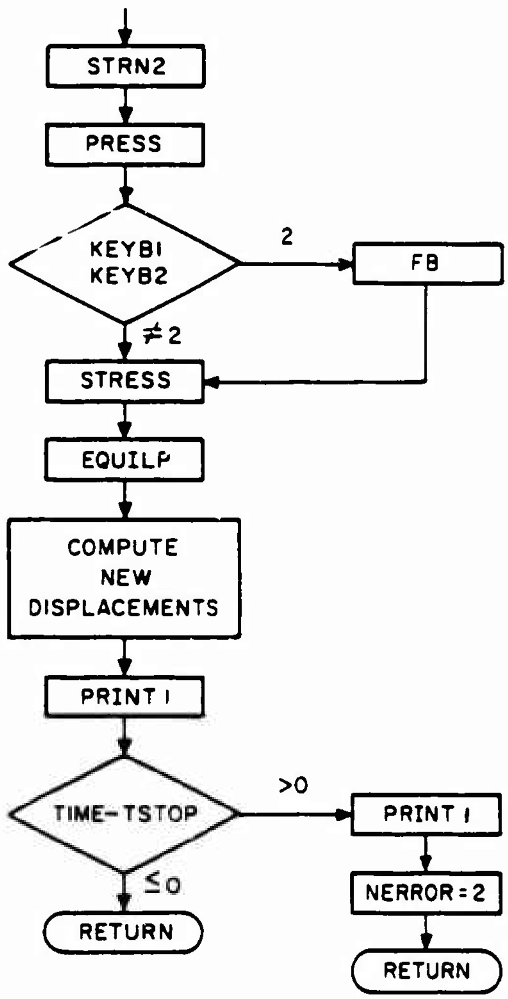


Figure 69. Subroutine CYCLE Flow Diagram

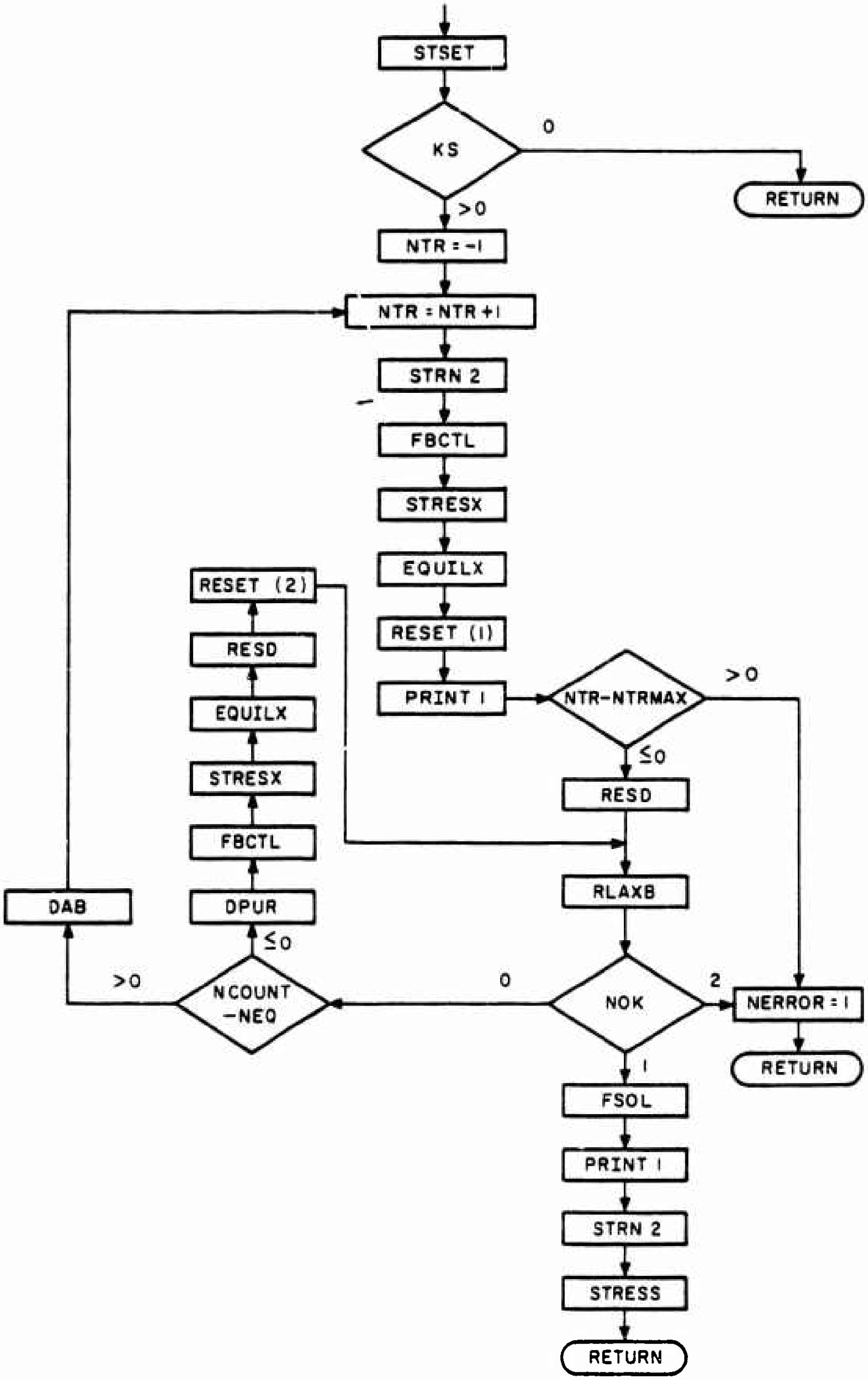


Figure 70. Subroutine DEFORM Flow Diagram

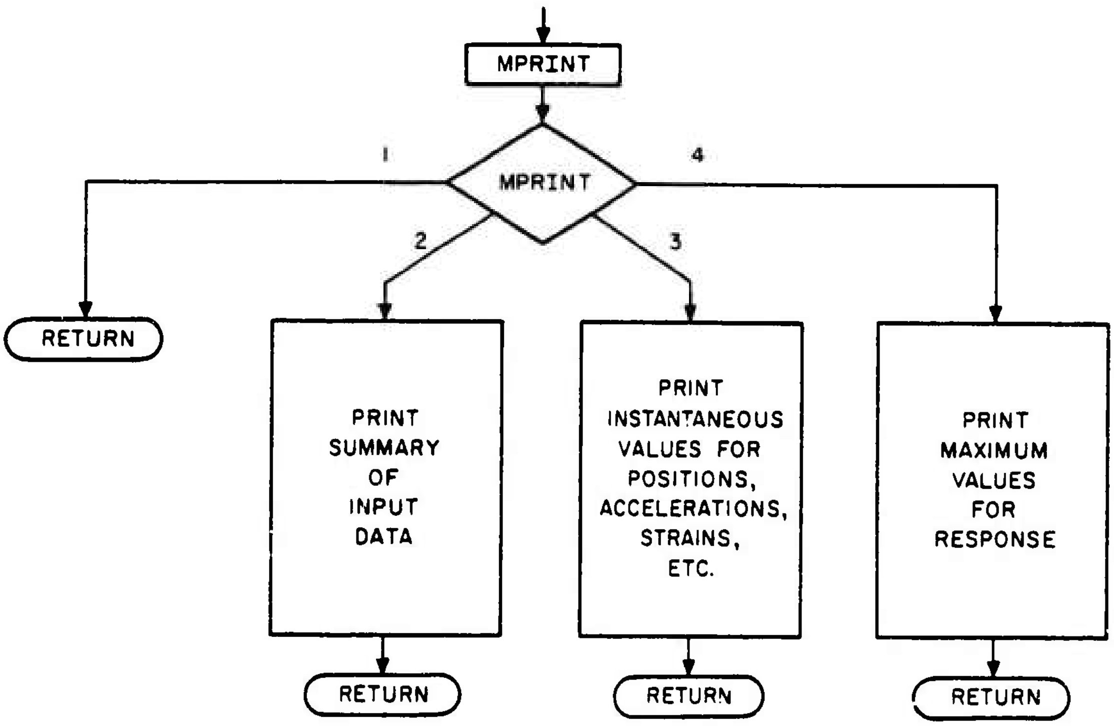


Figure 71. Subroutine PRINT1 Flow Diagram

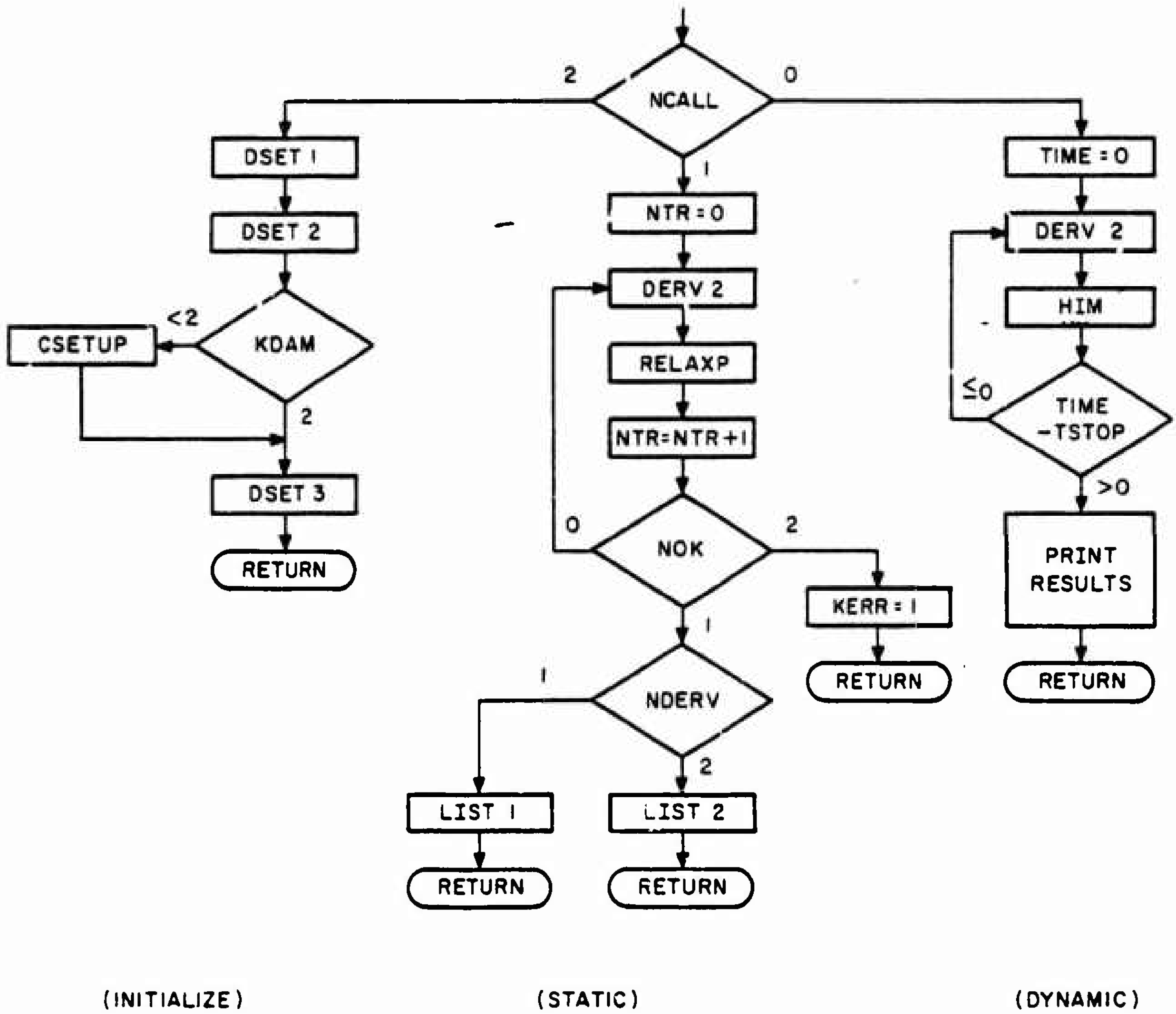


Figure 72. Subroutine DEPROP Flow Diagram

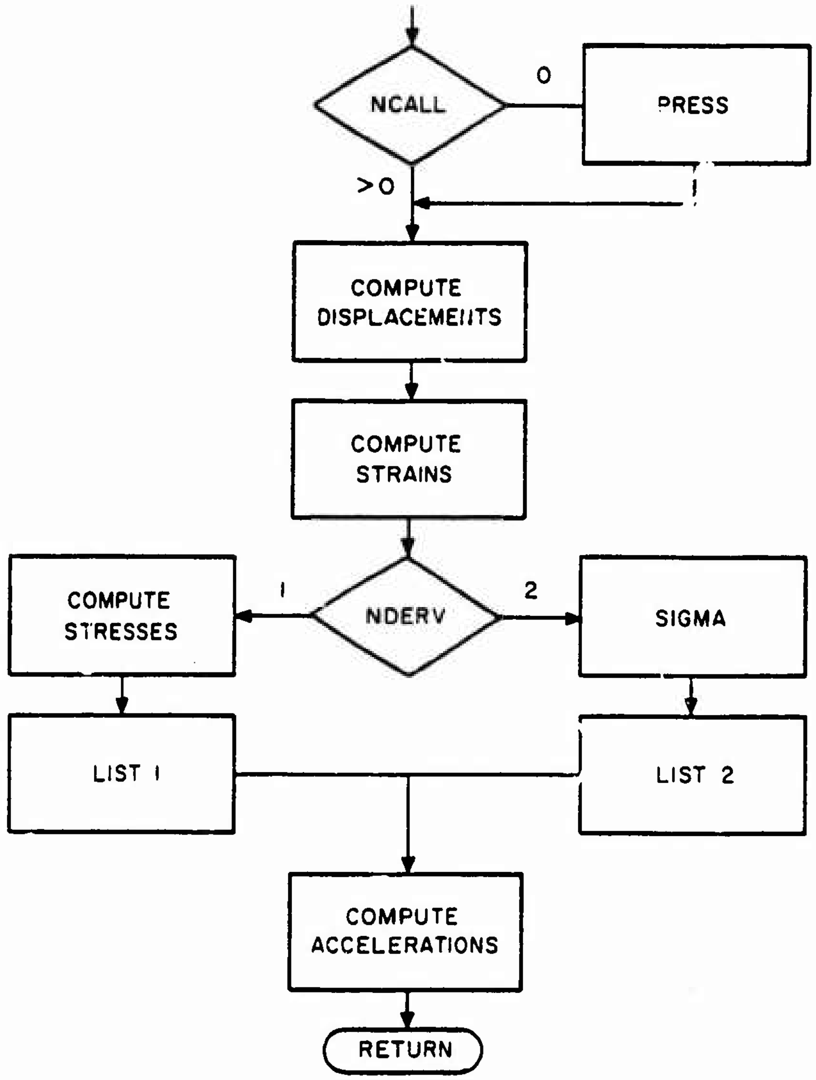


Figure 73. Subroutine DERV2 Flow Diagram

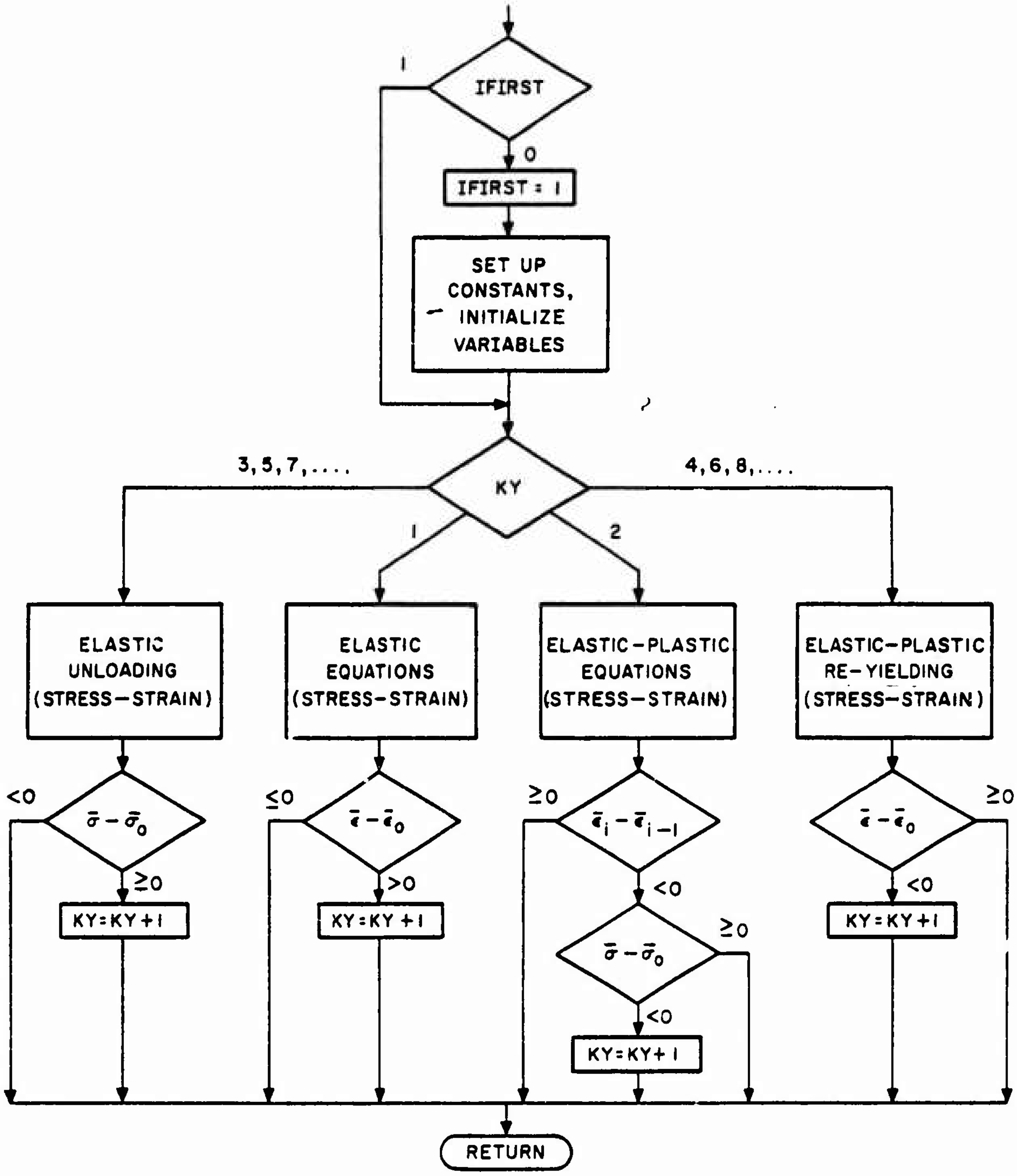


Figure 74. Subroutine SIGMA Flow Diagram

6.2 DEFINITION OF MAJOR PROGRAM VARIABLES

The major program variables are defined in paragraphs 6.2.1, 6.2.2, and 6.2.3 for the NOVA, DEPROB, and DEPROP routines, respectively. An asterisk preceding a variable name indicates that the variable is input as run data. The dimension of a variable is given parenthetically after the variable name. A numeric dimension indicates the fixed amount of storage required for the variable. There is no need to change the dimension of such a variable. However, other variables have variable dimensions. As an example, the first doubly dimensioned variable listed in paragraph 6.2.1 is FP(10,NMASS). The first dimension indicates a fixed amount of storage which is required regardless of changes that are made in other dimensions. The second dimension is a variable, NMASS, which represents the number of mass points in a structural element. This dimension must be the largest number of mass points the user intends to employ in a solution involving a beam element. In the NOVA program, this dimension is 40. If additional mass points are required, the dimension of NMASS must be increased, thus increasing the dimensions for all variables with the dimension, NMASS. Since the variable N represents the same quantity in the DEPROB routine as NMASS does in the NOVA routine, the dimensions for all variables with the dimension N would also have to be increased. The current dimensions provided for the variables in the NOVA, DEPROB and DEPROP routines are given in tables 17, 18, and 19.

Almost all of the variables which may require dimension changes as indicated above are contained in the COMMON blocks for the three routines. There are a few exceptions and, in such cases, the subroutine in which the variable is dimensioned is indicated in the list of variables or in table 20. If the dimensions are changed, certain additional changes in the program may be required. These changes are also indicated in table 20.

The axis system used in describing the program variables is described in table 21 and illustrated in figure 75. It should be emphasized that the aircraft axis system (AAS) must be centered at the center of gravity of the aircraft.

TABLE 17. DIMENSIONS OF VARIABLES FOR NOVA ROUTINE

VARIABLE	DIMENSION
NEL	20
NFS	20
NLE [1]	5
NLEHT	5
NLEVT	5
NLEW	5
NMASS	40
NORMAX	30
NORMAX*NEL	100
NTE [1]	5
NTEHT	5
NTEVT	5
NTEW	5
NTP1+1	1000

[1] NLE must be largest of NLEHT, NLEVT, NLEW and NTE must be largest of NTEHT, NTEVT, NTEW

TABLE 18. DIMENSION OF DEPROB VARIABLES

VARIABLE	DIMENSION
NX [1]	10
N [2]	40
NL [3]	8
NLK	20
NSL	5
NSSC [4]	5
NSSCT [5]	5

1 The program automatically assigns NX or fewer flanges to each layer, so NX should usually be four or six since the sum of all flanges must not exceed NLK.

2 NMASS in NOVA

3 For a uniform beam, the program may add one layer, so the actual limit on input would ordinarily be seven.

4 The number of distinct slopes defined by NSSC and NSSCT, excluding zero slope segments, must not exceed NSL.

TABLE 19. DIMENSIONS OF DEPROP VARIABLES

VARIABLE	DIMENSION
LBAR	6
MB [1]	7
MBAR	19
MBAR*NBAR*LBAR [2]	1156
MG [1]	7
NBAR	19
NL	8

1 Additional constraint: The total number of modes selected from the total possible (MB*MG) cannot exceed 25.

2 This constraint is only significant for an elastic-plastic run (NDERV=2). Three possible combinations using maximum dimensions are: (13x13x6), (15x15x5), (17x17x4).

TABLE 20. PROGRAM CHANGES REQUIRED BY DIMENSION CHANGES

When Changing the Dimensions Corresponding to:	Also Change the Fixed-Point Number in the Indicated Statement		
	Routine	Subroutine	Location [1]
NORMAX	NOVA	NOVA	5^{-1}
NORMAX*NEL	NOVA	NOVA	570^{+6}
NTP1+1	NOVA	WPRES	43^{-2}
MG*MB*3	DEPROP	HIM	COMMON BLOCK
LBAR	DEPROP	LEGEND	300^{-11}
MG*MB*3	DEPROP	RELAXP	20^{+1}
NL	DEPROB	COMP1	50^{-7}
NSL*NLK*2*(N+1)	DEPROB	COMP1	50^{-6}
NLK	DEPROB	COMP1	50^{-5}
NSL	DEPROB	COMP1	50^{-4}
N*2+2	DEPROB	RLAXB	40^{+3}

1 The location code is read as follows: s^{+n} refers to the nth line after statement number s.

TABLE 21. AXIS SYSTEMS USED IN DESCRIBING VARIABLES

AAS	Aircraft Axis System Centered at aircraft center of gravity, X-Y plane parallel to plane of wing, X axis positive forward and forming an angle equal to the aircraft angle of attack with a horizontal plane, Y axis positive in the direction of the right wing, Z axis positive upward.
HAAS	Horizontal Aircraft Axis System Obtained from AAS by rotation about the Y axis such that the X axis becomes horizontal.
EFAS	Earth-Fixed Axis System Centered at burst point, X-Y plane horizontal, X axis parallel to aircraft velocity vector. The EFAS thus results by translation of the HAAS.
LAS	Local Axis System Used for DEPROB only. Axis system is two-dimensional (y,z) in plane of structural element. For a stringer, longeron or rib the directions of y and z may be chosen at the convenience of the analyst. For a frame or a radome, either of which is assumed to lie parallel to the Y-Z plane of the AAS, the y-axis, LAS, is parallel to the Y-axis, AAS (i.e., in the direction of the right wing); and the z-axis, LAS, is parallel to the Z-axis, AAS (i.e., positive upward).

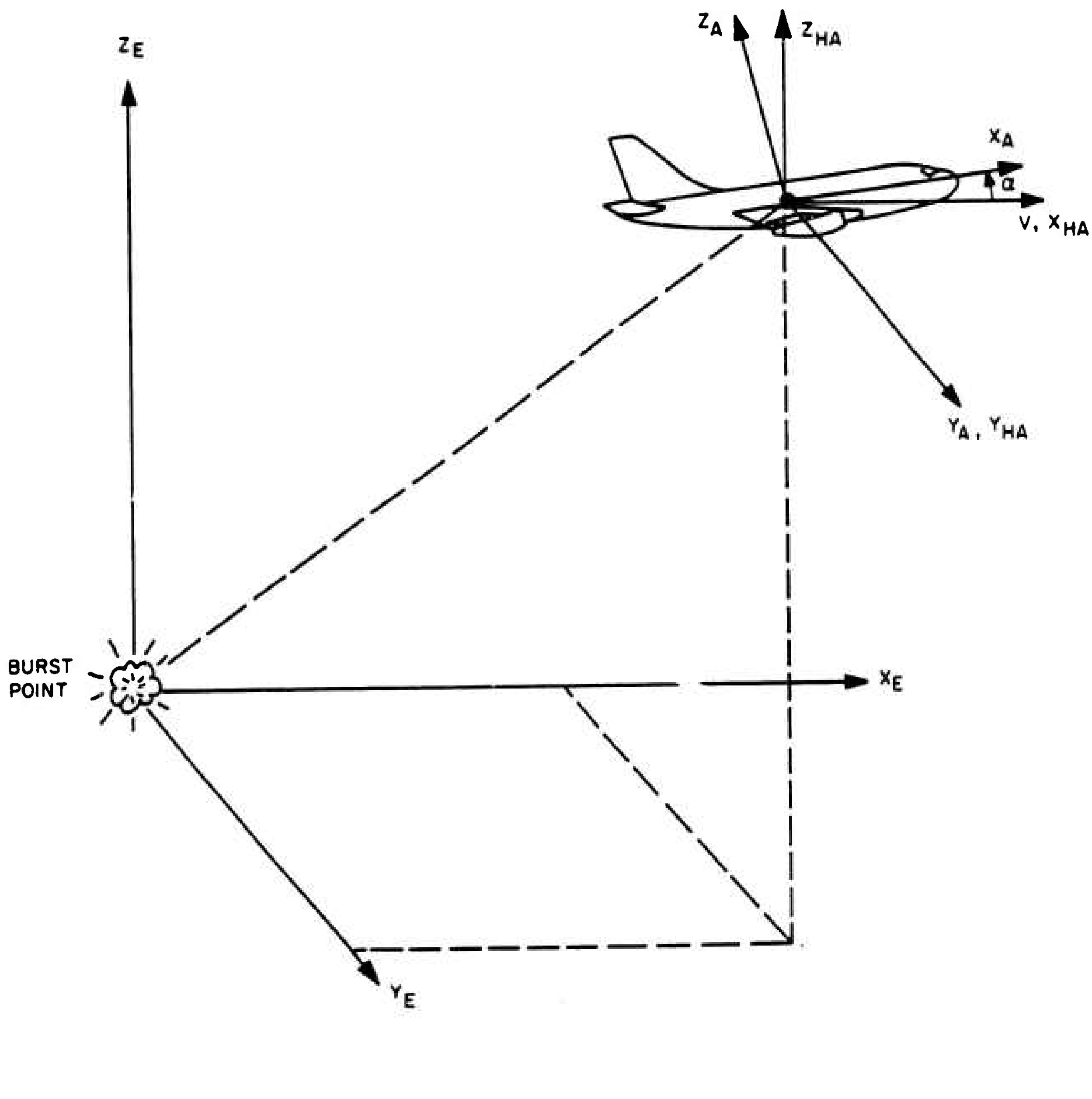


Figure 75. Earth-Fixed Axis System (x_E, y_E, z_E), Aircraft Axis System (x_A, y_A, z_A) and Horizontal Aircraft Axis System (x_{HA}, y_{HA}, z_{HA})

6.2.1 Major Program Variables for the NOVA Routine

*ALFAA	Aircraft angle of attack, rad
ALFAF	Fuselage axis angle of attack, rad (set equal to ALFAA)
*ALT	Aircraft altitude, ft
*BAF	Bend angle of the fuselage, β (fig. 26), rad
CORD	Chord length, ft
CRIT(5)	Response criterion equal to unity at critical range. The most recent value in CRIT(1); previous points in CRIT(2) - CRIT(4). Dimensionless
CO	Ambient speed of sound, ft/sec
*DELTIM	Integration time interval, sec
*DRDX	Rate of change of radius of equivalent fuselage cross section with x, where x is the fuselage axis, positive forward, dimensionless
FP(10,NMASS)	Pressure on fuselage point, lbs/in^2
GAMMA(NMASS+1)	Circumferential slope angle for fuselage frame or ring, rad
HB	Height of burst above ground, ft
*HG	Height of ground above sea level, ft
*HTINC	Horizontal tail incidence, rad
*ICOMP	Code designating aircraft component on which the structural element is located: 1, Wing 2, Fuselage 3, Horizontal tail 4, Vertical tail
*INOUT	Program output-option code: 0, do not print out input data 1, print out input data
*IUL	Code designating side of lifting surface being considered: 1, Upper surface (for vertical tail, right side) 2, Lower surface (for vertical tail, left side)

*KALT	Code designating whether iteration is at constant altitude: 0, no altitude restriction 1, iteration restricted to constant altitude
*KB	Code designating ground reflection model to be used: 1, REFRA tape based on REFLECT code. 2, Analytical model used in NOVA 1.
*KDAM	Damage level code: 0, no permanent damage 1, catastrophic damage 2, response run only
KDS	Not used in NOVA.
KERR	Error Code: 0, no error 1, problem encountered in FPRES, WPRES, DEPROB or DEPROP (Appropriate message is printed out)
KF	Code associated with calling BLAST with option 2. 1, check first shock for lack of data. 2, check second shock for lack of data.
*KGRD	Control constant for ground reflection: 0, no ground reflection 1, include ground reflection
KGRDO	Original value of KGRD
KOK	Range iteration code: 0, try another range 1, finished iteration 2, error
*KTYPE	Code designating structural type: 1, single-layer metal panel 2, single-layer plastic panel 3, honeycomb metal panel 4, honeycomb plastic panel 5, multilayer plastic panel 6, metal stringer or longeron 7, metal frame 8, metal ring 9, plastic ring 10, rib

NCALL	Code for number of call to DEPROB or DEPROP: 0, ensuing calls, find dynamic response. 1, second call, find preblast solution. 2, first call, read data
NCASE	Number of cases run, considering each orientation
NCHPT	Not currently used.
*NDBUG	Output debugging control constant: 0, no additional output 1, most additional output 2, all additional output
NEL	Number of the structural element being considered
*NFP	The number of the fuselage section at which pressures are desired
*NFS	Number of fuselage sections used to describe fuselage geometry
NLE	Number of points used to define leading edge
*NLEHT	Number of points used to define the leading edge of the horizontal tail
*NLEVT	Number of points used to define the leading edge of the vertical tail
*NLEW	Number of points used to define the leading edge of the wing
NMASS	Number of mass points in DEPROB structural element
*NOR	Number of orientation to be considered
*NORMAX	Number of last orientation to be considered
NORT	Total number of orientations considered.
NTE	Number of points used to define trailing edge
*NTEHT	Number of points used to define the trailing edge of the horizontal tail
*NTEVT	Number of points used to define the trailing edge of the vertical tail
*NTEW	Number of points used to define the trailing edge of the wing

NTP1	Number of times, minus one, at which pressures are calculated
NTRIAL	Number of the present trial in iteration for the critical range
OUT(8)	Storage for data returned from BLAST: OUT(1) = material velocity, ft/sec OUT(2) = pressure, lbs/in^2 OUT(3) = density, slugs/ft^3 OUT(4) = speed of sound, ft/sec OUT(5) = ratio of specific heats, dimensionless OUT(6) = x component of material velocity, ft/sec OUT(7) = y component of material velocity, ft/sec OUT(8) = z component of material velocity, ft/sec
PB(NMASS)	Net pressure acting on mass point for DEPROB, lbs/in^2
*PDAM	Probability of exceeding specified damage level, expressed as a fraction, dimensionless
*PINT	Input as internal pressure above ambient, changed by program to absolute internal pressure, lbs/in^2
PPP	Net pressure acting on panel for DEPROP, lbs/in^2, net axial force acting on a rib for DEPROB, lbs
*PRINT	Number of time intervals between printouts (0.0 will give no printout), dimensionless
PO	Ambient pressure, lbs/in^2
RCRIT(100)	Critical range for each element for each orientation, ft
*REST(NORMAX)	Estimated range at shock arrival time, ft
*RF(NFS)	Radius of equivalent fuselage, in
RFR	Radius of equivalent fuselage at section NFP, in
RHOO	Ambient density, slugs/ft^3
RTRIAL(5)	Trial ranges (current trial range in RTRIAL(1), previous values in RTRIAL(2) - RTRIAL(5)), ft
SL	Slope of leading edge, dimensionless
SSPAN	Effective semispan, ft
ST	Slope of trailing edge, dimensionless

TFP(10,NMASS)	Time corresponding to FP, sec
*THETAR	Angular location of the center of the structural element (panel, stringer, or longeron) on the circumference of the equivalent circular section for the fuselage and the point at which the pressures are applied (see Fig. 19), rad
TIME	Time, sec
*TITLE(20)	Title card - description of aircraft, date, etc.
*TSTOP	Time after-shock intercept at which computations are to stop, sec
TLX	Time corresponding to last data on REFRA tape, sec
TWP(NTP1+1)	Time corresponding to WP, sec
*VEL	Aircraft velocity, ft/sec
*WKT	Weapon yield, KT
WP(NTP1+1)	Pressure on lifting surface point (wing, horizontal tail, or vertical tail), lbs/in^2
*XB(NFS)	X coordinate (AAS) of fuselage section, in
*XBF	X coordinate (AAS) of fuselage station at which bend angle, BAF, occurs (see fig. 26), in
XCC(NFS)	X coordinate (HAAS) of center of equivalent fuselage circular cross section, ft
XCW	Chordwise distance from leading edge to point at which pressure is desired, ft
XLE(NLE)	X coordinate (AAS) of point used to define leading edge, in
*XLEHT(NLEHT)	X coordinate (AAS) of point used to define horizontal tail leading edge, in
*XLEVT(NLEVT)	X coordinate (AAS) of point used to define vertical tail leading edge, in
*XLEW(NLEW)	X coordinate (AAS) of point used to define wing leading edge, in
XLL	X coordinate (AAS) of leading edge at spanwise station YSW, ft
*XNOSE	X coordinate (AAS) of nose of fuselage, in

*XOSRO(NORMAX)	X direction cosine (EFAS) of orientation, dimensionless (input only for orientation numbers greater than 2i)
XOSRB(NORMAX)	Original set of XOSRO's prior to range iteration.
*XP	X coordinate (AAS) of point at which pressure is desired, in
XSA	X componenc of vector from burst point to aircraft cg at shock arrival time (EFAS), ft
XSCRIT(100)	Critical value of XSA for each orientation and structural element, ft
*XTAIL	X coordinate (AAS) of tail of fuselage, in
XTE(NTE)	X coordinate (AAS) of point used to define trailing edge, in
*XTEHT(NTEHT)	X coordinate (AAS) of point used to define horizontal tail trailing edge, in
*XTEVT(NTEVT)	X coordinate (AAS) of point used to define vertical tail trailing edge, in
*XTEW(NTEW)	X coordinate (AAS) of point used to define wing trailing edge, in
XTL	X coordinate (AAS) of trailing edge at spanwise position YSW, ft
YCC(NFS)	Y coordinate (HAAS) of center of equivalent fuselage circular cross section, ft
*YF	Y coordinate (AAS) of center of fuselage (YF will ordinarily be 0.0; it is included to accommodate external stores or nacelles), in
YLE(NLE)	Y coordinate (Z coordinate for vertical tail) (AAS) of point used to define leading edge, in
*YLEHT(NLEHT)	Y coordinate (AAS) of point used to define horizontal tail leading edge, in
*YLEW(NLEW)	Y coordinate (AAS) of point used to define wing leading edge, in
*YOSRO(NORMAX)	Y direction cosine (EFAS) of orientation, dimensionless (input only for orientation numbers greater than 21)

YOSRB(NORMAX)	Original set of YOSRO's prior to range iteration
*YP	Y coordinate (AAS) of point at which pressure is desired, in
YSA	Y component of vector from burst point to aircraft cg at shock arrival time (EFAS), ft
YSCRIT(100)	Critical value of YSA for each orientation and structural element, ft
YSW	Spanwise location of point at which pressure is desired, ft
YTE(NTE)	Y coordinate (Z coordinate for vertical tail) (AAS) of point used to define trailing edge, in
*YTEHT(NTEHT)	Y coordinate (AAS) of point used to define horizontal tail trailing edge, in
*YTEW(NTEW)	Y coordinate (AAS) of point used to define wing trailing edge, in
ZCC(NFS)	Z coordinate (HAAS) of center of equivalent fuselage circular cross section, ft
*ZF	Z coordinate (AAS) of fuselage axis, in
*ZLEVT(NLEVT)	Z coordinate (AAS) of point used to define vertical tail leading edge, in
*ZOSRO(NORMAX)	Z direction cosine (EFAS) of orientation, dimensionless (input only for orientation numbers greater than 21)
ZOSRB(NORMAX)	Original set of ZOSRO's prior to range iteration.
*ZP	Z coordinate (AAS) of point at which pressure is desired, in
ZSA	Z component of vector from burst point to aircraft cg at shock arrival time (EFAS), ft
ZSCRIT(100)	Critical value of ZSA for each orientation and structural element
*ZTEVT(NTEVT)	Z coordinate (AAS) of point used to define vertical tail trailing edge, in
ZZ1(9)	Unused storage
ZZ2(9)	Unused storage

6.2.2 Major Program Variables for DEPROB Routine

ACCNV(N+1)	Acceleration in the y direction (LAS), in/sec^2.
ACCNW(N+1)	Acceleration in the z direction (LAS), in/sec^2.
AFL(NL,N+2)	Cross-sectional area of a flange, in^2.
*AMP	Amplitude of initial lateral displacement (imperfection) in rib element, in.
ASRL(NSL,NL)	Area ratio of sublayer, c_K, in mechanical sublayer model, dimensionless.
BAV(10,2)	Resultant internal axial force in clamped edge segment, lbs.
BBV(10,2)	Resultant internal moment in clamped edge segment, in-lbs.
BIGM(N+1)	Resultant internal moment, in-lbs.
BIGMP(2)	Resultant moment acting on end of clamped edge segment, in-lbs.
BIGN(N+1)	Resultant internal axial force, lbs.
*BIGR3	Radius to center of cross section, in.
BMP1(2)	Previous value of BIGMP, in-lbs.
CCRIT(NL)	Critical compressive stress of layer, lbs/in^2.
CEA(2)	Elastic axial force due to unit axial strain in clamped edge segment, lbs.
CEZA(2)	Elastic bending moment due to unit axial strain in clamped edge segment, in-lbs.
CEZ2A(2)	Elastic bending moment due to unit rotational strain in clamped edge segment, lb-in^2.
CINST(3)	Critical compressive instability stress, lbs/in^2.
COSG(N)	Average of COST for two adjacent links in undeformed state, dimensionless.
COST(N+1)	Cosine of the angle a bar makes with the y-z coordinate frame (LAS), dimensionless.
COSTM(N+1)	Value of COST after each trial in static solution.

CPTIM	Accumulated computer (CP) time, sec.
CTET(11,2)	Cosine of slope angle in clamped edge segment, dimensionless.
CTH2	Cosine of angle last bar makes with perpendicular to plane of symmetry, set to 1.0 after rotation, dimensionless.
CTP1(10,2)	Average value of cosine of slope angle in clamped edge segment, dimensionless.
CT1	Cosine of the angle the first end of the beam makes with the y-z coordinate frame (LAS), dimensionless.
CT2	Cosine of the angle the second end of the beam makes with the y-z coordinate frame (LAS), dimensionless.
C6(N+1)	Inverse of the mass of a point, in/lb-sec^2.
DELTAS(N+1)	Length of a bar joining two adjacent masses, in.
*DELTIM	Integration time interval, sec.
DELTS(N+1)	Original average length of two adjacent bars, in.
DELTSM(N+1)	Length of bar at the previous time, in.
DELTSO(N+1)	Original length of bar, in.
DELTT(N+1)	Bend angle at mass point, rad.
DELTTM(N+1)	Bend angle at mass point at the previous time, rad.
DELTTO(N+1)	Original bend angle at mass point, rad.
DELX(2N+2)	Amount by which variables are perturbed in RLAXB, in. or rad.
DEL3	Value of DELTTO(N1), retained during static solution for KS=7, rad.
DEN(2)	Elastic constant related to CEA, CEZA, and CEZ2A, (in-lb)^2.
DIS(N)	Absolute value of total displacement, in.
DUMK	Equal to DELTIM squared, sec^2.
ECMXI(NL)	Maximum compressive strain in the innermost flange, in/in.

ECMXO(NL)	Maximum compressive strain in the outermost flange, in/in.
*EI(N)	Stiffness of supporting longeron, EI, $lb\text{-}in^2$.
*ELL	Length of supporting longeron, in.
EPSILL(N+1)	Strain in the inner layer, in/in.
EPSILU(N+1)	Strain in the outer layer, in/in.
ER(3)	Error tolerance used in trial and error solution for clamped edge segment, lbs, lbs, in-lbs.
ERR	Constant used in setting error allowed in the static solution, dimensionless.
ERRR(2N+2)	Error in static solution, in or rad.
ETMXI(NL)	Maximum tensile strain in the innermost flange, in/in.
ETMXO(NL)	Maximum tensile strain in the outermost flange, in/in.
FN(NSL,NLK,2N+2)	Stress in each sublayer of each flange, lbs/in^2.
FNFL(NL)	Number of flanges in a layer, dimensionless.
FNX	Equal to NX.
FSKIN	Inward acting spring constant normalized to skin thickness, taking into account membrane force of skin, lb/in^2.
FY(N+1)	Externally applied force in the y direction (LAS), lbs.
FZ(N+1)	Externally applied force in the z direction (LAS), lbs.
*H(NL,N+2)	Thickness of layer, in.
HF(2)	Horizontal force (parallel to end of beam) acting on end of clamped edge segment, lbs.
HP1(2)	Previous value of HF, lbs.
HT(N+2)	Total thickness of cross section, in.
IL1(2)	Lower limit of indices when looping on mass points; equal to 1 except for clamped or free edge, when it is 2.

IL2	Equal to IL1(2).
IP(2N+2)	Working array in RLAXB.
*IPROP(NL)	Key as to whether the material properties are the same in tension and compression: 0, same 1, different
IU	Upper limit on indices during static solution.
IU1(2)	Upper limit of indices when looping on mass points. Equal to N except: N-1 for clamped or free edge when computing BIGM; N+1 for S.S. edge or free ring when computing BIGN. The first value corresponds to BIGN; the second to BIGM.
IU2	Equal to IU1(2)
IY(N+1)	Code as to whether link has yielded, equal to either IY1 or IY2.
IY1	Hollerith constant equal to a blank, signifying no yield.
IY2	Hollerith constant equal to an asterisk, signifying yield.
JTIM	Number of integration steps which have elapsed.
KEL	Code as to whether run is elastic (1) or elastic-plastic (0).
*KEYB1	Boundary condition code at first end: 1, free ring 2, clamped 3, simply supported 4, free
*KEYB2	Boundary condition code at second end: 1, free ring 2, clamped 3, simply supported 4, free 5, symmetric
*KEYRG	Key as to whether the structure is circular: 1, circular 2, not circular
KFREE	Code as to whether the structure is completely free of any restraints: 0, not free 1, free

*KIS	Code as to definition of inner surface: 1, inner surface is on left when proceeding from first end to second - corresponds to counter-clockwise direction for full ring, in local Y-Z coordinate frame (LAS). Represents orientation consistent with that used in NOVA-1. 2, inner surface is on right.
KMAX	Code designating where maximum strain occurred: 1, outer layer 2, inner layer
KS	Code designating seven different boundary condition combinations solvable statically.
*KSUP	Support code for outstanding (inner) leg: 0, no outstanding leg 1, supported on one end 2, supported on both ends.
*KUNF	Code specifying whether beam is uniform in spanwise direction: 0, not uniform 1, is uniform
LMAX	Link in which maximum response occurred.
LSCMXI(NL)	Number of the bar in which ECMXI occurred.
LSCMXO(NL)	Number of the bar in which ECMXO occurred.
LSTMXI(NL)	Number of the bar in which ETMXI occurred.
LSTMXO(NL)	Number of the bar in which ETMXO occurred.
MAXF	Equal to MAXSF*MAXLK*2*N1.
MAXLK	Maximum number of flanges the program is dimensioned for.
MAXSF	Maximum number of distinct stress-strain slopes the program is dimensioned for.
MMAX	Code as to whether maximum response occurred in tension or compression: 1, tension 2, compression.

MPRINT	Output code for subroutine PRINT1: 1, no output 2, summary of constants is to be printed 3, dynamic response is to be printed 4, summary of results from the dynamic response is to be printed.
MTAPE	Logical file number used for output, equal to Tape 6.
MYIELD	Number of the integration step corresponding to the first yielding.
M1	Printout begins after M1 time intervals.
M2	The dynamic response will be printed every M2th time step.
*N	Number of masses in model.
*NAY(N)	Mass point number corresponding to variable EI at which elastic supporting element is attached.
NCMP	Program flow code (equal to NCALL in NOVA): 0, dynamic response 1, static solution 2, read data and initialize code.
NCOUND	Number of the variable in RLAXF which has been perturbed.
NCOUNT	Number of the variable in RLAXB which has been perturbed.
NEQ	Number of variables (and residues) in RLAXB.
NERROR	Code which terminates the program: 0, program continues 1, error in program 2, program stopped normally.
*NL	Number of layers in the cross section of the structural element.
NLK	Total number of flanges used in model.
NM1	Equal to N-1.
NPRINT	Debugging code controlling printout during static solution (equal to NDBUG of NOVA)· 0, no printout 1, printout results of each trial 2, printout results of each perturbation and each trial.

*NSEL	Number of (elastic) supporting elements.
NSKIN	Code as to whether membrane force due to skin is appropriate (frames only) 0, not appropriate 1, is appropriate
NSL(NL)	Number of sublayers (stress-strain model).
*NSSC(NL)	Number of stress-strain segments used for compression.
*NSSCT(NL)	Number of stress-strain segments used for tension.
NTAPE	Logical file number used for input, equal to five.
NTI(2)	Number of trials quasi-static edge solution required at edge 1 or 2.
NTR	Number of trials which have elapsed in finding static equilibrium.
NTRMAX	Maximum number of trials permitted in the static solution.
*NX	Maximum number of flanges in any layer.
NYIELD	Code which is responsible for printout of the dynamic response at the time when the structure first yields: 0, not first yielding 1, first yielding
N1	Equal to N+1.
N2	Equal to N+2.
PI	Constant equal to π.
PRES(2N+2)	Working array in RLAXB.
*PRINT	Printout interval (0.0 will give no printout), dimensionless
PX(2N+2)	Working array in RLAXB.
Q(N+1)	Internal shear force, lbs.
RATIO(NL)	Quantity used in determining the number of flanges in a layer, dimensionless.
RES(2N+2)	Residues used in the relaxation procedure for the static solution, in, rad, or in/sec^2.
RFY	Rigid body force in y-direction (LAS), lb.

RFZ	Rigid body force in z-direction (LAS), lb.
*RHO(NL)	Density of layer, lb-sec^2/in^4.
RRES(2N+1)	Base set of residues in RLAXB, in, rad, or in/sec^2
SAV(10,2)	Axial strain in clamped edge segment, in/in.
SAVP1(10,2)	Previous value of SAV, in/in.
SBV(10,2)	Rotational (bending) strain in clamped edge segement, rad/in.
SBVP1(10,2)	Previous value of SBV, rad/in.
SCM(NSL,NL)	Fictitious compressive breakpoint stress used in mechanical sublayer model, lb/in^2.
SCMXI(NL)	Stress corresponding to ECMXI for KDAM=0, lbs/in^2.
SCMXO(NL)	Stress corresponding to ECMXO for KDAM=0, lbs/in^2.
SIGX(2N+2)	Working array in RLAXB.
SING(N)	Average SINT for two adjacent links in undeformed state, dimensionless.
SINT(N+1)	Sine of the angle a bar makes with the y,z coordinate frame (LAS), dimensionless.
SINTM(N+1)	Value of SINT after each trial in static solution, dimensionless.
SM(N+2)	Mass of an individual point, lb-sec^2/in.
SMASH(N+1)	Working array in DEFORM.
SMASSF	Total mass, lb-sec^2/in.
SMASST	Total mass, lbs
SSS(NL,NSSC+1)	Stress-strain slope in compression, lbs/in^2
SSST(NL,NSSCT+1)	Stress-strain slope in tension, lbs/in^2
STET(11,2)	Sine of slope angle in clamped edge segment, dimensionless
STH2	Sine of angle last bar makes with perpendicular to plane of symmetry, set equal to 0.0 after rotation, dimensionless.

STM(NSL,NL)	Fictitious tensile breakpoint stress used in mechanical sublayer model, lb/in^2.
STMXI(NL)	Stress corresponding to ETMXI for KDAM=0, lbs/in^2.
STMXO(NL)	Stress corresponding to ETMXO for KDAM=0, lbs/in^2.
STP1(10,2)	Average value of sine of slope angle in clamped edge segment, dimensionless.
STRA(NSL,NLK,20)	Stress in sublayer of flange in clamped end segment, lbs/in^2.
*STRNA(NL, NSSC)	Strain at break point on the stress-strain curve for compression, in/in.
*STRNAT(NL,NSSCT)	Strain at break point on the stress-strain curve for tension, in/in.
*STRSO(NL,NSSC)	Stress at break point on the stress-strain curve for compression lbs/in^2.
*STRSOT(NL,NSSCT)	Stress at break point on the stress-strain curve for tension, lbs/in^2.
ST1	Sine of the angle the first end of the beam makes with the y-z coordinate frame (LAS), dimensionless.
ST2	Sine of the angle the second end of the beam makes with the y-z coordinate frame (LAS), dimensionless
SUMH(NL)	Quantity used in determining the center of gravity of the cross section, in.
TCRIT(NL)	Critical tensile stress for KDAM=0, lbs/in^2; critical tensile strain for KDAM=1, in/in.
TEND1	Angle the first end of the beam makes with the y-z coordinate frame (LAS), rad.
TEND2	Angle the second end of the beam makes with the y-z coordinate frame (LAS), rad.
TH	Angle last bar makes with perpendicular to plane of symmetry, rad.
THETA(N+1)	Angle locating a mass, measured from the negative z axis (LAS), rad.
*THETA1	Angle locating the first end of beam, measured from the negative z axis (LAS), rad.

*THETA2	Angle locating the second end of beam, measured from the negative z axis (LAS), rad.
TIME	Time from the beginning of the dynamic response, sec.
TSCMXI(NL)	Time corresponding to ECMXI, sec.
TSCMXO(NL)	Time corresponding to ECMXO, sec.
TSTMXI(NL)	Time corresponding to ETMXI, sec.
TSTMXO(NL)	Time corresponding to ETMXO, sec.
*TSTOP	Time at which computations are to stop, sec.
*V(N+1)	Y coordinate (LAS) of a mass, in.
VAR(2N+2)	Variables used in the relaxation procedure for the static solution, in. or rad.
VF(2)	Vertical force (perpendicular to end of beam) acting on end of clamped edge segment, lbs.
VM(N+1)	Y-coordinate (LAS) of a mass at the previous time, in.
VO(N+1)	Y-coordinate (LAS) of point corresponding to undeformed state, in.
VP1(2)	Previous value of VF, lbs.
*V1	Y-coordinate (LAS) of the first end of beam, in.
*V2	Y-coordinate (LAS) of the second end of beam, in.
V2M	Y-coordinate (LAS) of second end of beam after each trial in static solution, in.
V2O	Y-coordinate (LAS) of second end of beam as initially specified.
*W(N+1)	Z-coordinate (LAS) of a mass, in.
WM(N+1)	Z-coordinate (LAS) of a mass at the previous time, in.
WO(N+1)	Z-coordinate (LAS) of point corresponding to undeformed state, in.
*WR(NL,N+2)	Width of layer, in.
WRAT(N+2)	Ratio of width of layer to WT, dimensionless.

*WT	Width of skin over which pressure acts for longerons, frames; effective loading depth for ribs, in.
*W1	Z-coordinate (LAS) of the first end of beam, in.
*W2	Z-coordinate (LAS) of the second end of beam, in.
W2M	Z-coordinate (LAS) of second end of beam after each trial in static solution, in.
W2O	Z-coordinate (LAS) of second end of beam as initially specified, in.
X(11)	Position of point on clamped edge segment measured perpendicular to wall, in.
Y(11)	Position of point on clamped edge segment measured parallel to wall, in.
XEH(NL)	Quantity used in defining the flanges in a layer, lbs/in.
XRES(2N+2,2N+2)	Working array in RLAXB.
XX(2N+2)	Working array in RLAXB.
YCGO	Distance from the outer surface to the center of gravity of the cross section, in.
YCG1(N+2)	Algebraic difference between distance to center of cross section and distance to center of gravity of cross section, in.
ZETA(NLK,N+2)	Distance from the center of gravity of the cross section to a flange, positive inward for KIS=1. Positive outward for KIS=2, in.
ZETAL(N+2)	Value of ZETA to outermost flange in cross section, in.
ZETAU(N+2)	Value of ZETA to innermost flange in cross section, in.

6.2.3 Major Program Variables for DEPROP Routine

*A	Radius of the cylindrical panel, a, in. Is set equal to 1.0 for flat panel.
BETR(NBAR)	Integration positions in the beta-direction, rad.
BTL(NL)	Constants used in elastic option, $E_\theta^k/(1-\nu_x^k\nu_\theta^k)$, psi.
BXL(NL)	Constants used in elastic option, $E_x^k/(1-\nu_x^k\nu_\theta^k)$, psi.
CCRIT(NL)	Critical compressive stress of layer, psi.
CC1(MG)	Constant, 2m-1, dimensionless.
CC2(MB)	Constant, 2n-1, dimensionless.
CC5(MG)	Constant, 2m, dimensionless.
CC6(MB)	Constant, 2n, dimensionless.
CINST(3)	Critical compressive instability stress, psi.
CK(6)	Constants, $1/k_\gamma$, $1/k_\beta$, for the equations of motion, dimensionless.
CM11,CM12, CM22,CM33	Stiffness constants C_{ij} used in elastic, multilayer integration through the thickness, lb/in.
CN10	Constant, $2\ell^2R/\pi^2a^2$ for elastic option, $2\ell^2/\pi^2a^2$ for elastic-plastic option, dimensionless.
CN11	Constant, $\ell^2/6\pi^2a^2R^2$ for elastic option, $2\ell^2/\pi^2a^2$ for elastic-plastic option, dimensionless.
CN6	Constant for elastic-plastic option, $E/(1-\nu^2)$, psi.
CN7	Shear modulus for elastic-plastic option, $E/2(1+\nu)$, psi.
CN8	Constant, ℓ^2/π^2a^2, dimensionless.
CN9	Constant, $\ell^2/4\pi^2a^2R^2$, dimensionless.
COSB(MB*NBAR)	Cosine functions of the beta angles, cos $(2n\beta_j)$, dimensionless.
COSG(MG*MBAR)	Cosine functions of the gamma angles, cos $(2m\gamma_i)$, dimensionless.

COS2B(MB*NBAR)	Cosine functions of the beta angles, cos $((2n-1)\ \beta_j)$, dimensionless.
COS2G(MG*MBAR)	Cosine functions of the gamma angles, cos $((2m-1)\gamma_i)$, dimensionless.
*DC	Core cell size, in.
*DELTIM	Integration time interval, sec.
DELX(3*MG*MB)	Working array in RELAXP, dimensionless.
DM11, DM12, DM22, DM33	Stiffness constants D_{ij} used in elastic, multilayer integration through the thickness, lb-in.
DPRT	Running time, in multiples of DPRT1, used to flag next printout, sec.
DPRT1	Time interval between printouts, sec.
DWB(MBAR,NBAR)	Values for imperfection-related partial derivative $\overset{\circ}{W}_\beta$, dimensionless
DWG(MBAR*NBAR)	Values for imperfection-related partial derivatives $\overset{\circ}{W}_\gamma$, dimensionless.
DWO(MBAR*NBAR)	Values for imperfection-related displacement $\overset{\circ}{W}$, dimensionless.
*EC	Core modulus of elasticity, parallel to core depth, psi.
EL	Modulus of elasticity for elastic-plastic option, E, psi.
*EM(NL)	Modulus of elasticity for each layer for elastic-plastic option, E^k, psi.
*EP	Strain hardening slope for elastic-plastic option, E_t, psi.
EPBO(LMAX)	Equivalent stress, squared, when response is still elastic for the elastic-plastic option, $\bar{\sigma}^2$, lb^2/in^4.
EPO	Equivalent yield strain corresponding to SIGO for elastic-plastic option, $\bar{\varepsilon}_o$, in/in.
*EPSIF	Ultimate (fracture) strain for elastic-plastic option, ε_f, in/in.

ERR(3*MG*MB)	Allowable error in displacement coefficients in the static preblast solution.
*ET(NL)	Modulus of elasticity in the theta-direction for elastic option, E_θ^k , psi.
ETT	Temporary value of strain, $\epsilon_{\theta\theta}^m$, in/in.
*EX(NL)	Modulus of elasticity in x-direction for elastic option, E_x^k, psi.
EXT	Temporary value of strain, $\bar{\epsilon}_{x\theta}^m$, in/in.
EXX	Temporary value of strain, $\bar{\epsilon}_{xx}^m$, in/in.
*FG(MB,MG)	Modal displacement coefficients for the initial imperfections, in.
FM11, FM12 FM22, FM33	Stiffness constants F_{ij} used in elastic, multilayer integration through the thickness, lb.
FP1, FP2, FP3, FP4, FP5, FP6	Spatial integration functions corresponding to the edge conditions selected, dimensionless.
GAM(MBAR)	Integration positions in the γ-direction, rad.
*GC	Shear modulus of core, psi.
GX(LBAR)	Zeroes of the Legendre polynomial for the elastic-plastic Gaussian integration through the thickness, ξ_i, dimensionless.
*GXT(NL)	Shear modulus, $G_{x\theta}$, psi.
H	Thickness of cross section for elastic-plastic option, in.
HBAR	Distance from the inner panel surface to the coordinate surface, $\bar{H}$, in.
HGO(LBAR)	Weighting factors for the elastic-plastic Gaussian integration through the thickness, H_i, dimensionless.
*HM(NL)	Distance from the inner panel surface to the outer surface of layer, h, in.
IFIRST	Code designating first pass through subroutine SIGMA, dimensionless.

INZ(2)	Code designating the appropriate layer number corresponding to the two panel surfaces, dimensionless.
IP(3*MG*MB)	Working array in RELAXP, dimensionless.
JFIRST	Code which indicates if the panel has yielded for the elastic-plastic option.
KC	Counter for determining whether strains should be compared with critical values. Values are only checked every tenth time step to save computer time.
KDS	Static-dynamic option code. Always 3 in NOVA.
KSUMA(MBAR*NBAR)	Number of z points which have not yielded at each spatial station. Used only in elastic-plastic option.
KY(LMAX)	Code in elastic-plastic response, indicating number of times an integration point has yielded, unloaded, etc.
KZ	Code deciding whether the output routine should print, check maximum values, or both.
*LBAR	Number of integration points through the thickness. Is assumed to be one for elastic option.
LMAX	Maximum number of integrated points being used. Equal to MBAR*NBAR*LBAR.
*MB	Number of beta modes to be incorporated into the solution.
*MBAR	Number of beta integration points to be used. For a symmetric boundary condition, only approximately half as many points are required.
*MG	Number of gamma modes to be incorporated into the solution.
MGM(MG)	Gamma mode numbers.
MGMB	Constant, equal to the total number of modal combinations used, MG*MB-NNOUT.
MGMB2	Constant, 2*MGMB.
*MOUT(MG*MB)	Gamma modes <u>not</u> to be included, in combination with the corresponding NOUT mode.
MUSE(MB,MG)	Code designating which modal combinations are to be used.

*NBAR	Number of gamma integration points to be used. For a symmetric boundary condition, only approximately half as many points are required as otherwise.
NBN(MB)	Beta mode numbers.
*NBND	Boundary condition code.
NBT	Same as NBAR.
*NDERV	Response code: 1-elastic (multilayer, orthotropic), 2-elastic-plastic (single layer, isotropic).
NELP	Response code for the elastic-plastic option: 1-keep solution elastic, 2-allow solution to go elastic-plastic.
NGNB	The spatial integration point number corresponding to the center of the panel.
NGT	Same as MBAR.
*NL	Number of layers.
NLZ(16)	Layer number corresponding to each layer's upper and lower surfaces.
*NNOUT	Number of modal combinations (<MG*MB) to be eliminated from the solution.
NOUT(MG*MB)	Beta modes <u>not</u> to be included, in combination with the corresponding MOUT mode.
*NPLT	Panel type code: 0-flat, 1-curved.
NREG	Elastic plastic region number corresponding to the maximum response during an iteration run.
NSYMB	Symmetry code in the beta-direction (depends on boundary conditions): 0-symmetric, 1-not symmetric.
NSYMG	Same as NSYMB, except in the gamma-direction.
NTECO	Code indicating whether maximum response occurred in tension or compression on an iteration run: 1-tension, 2-compression.
NU	Code indicating whether loading is spatially uniform or not: 0-not uniform, 1-uniform. In NOVA the loading is <u>always</u> assumed to be uniform.

NUSE	Use code for the spatial integration stations: 0-not used, 1-used for printout only, 2-used for integration only, 3-both.
NY2	Constant, equal to 3*MGMB.
NZP	Number of z points to be checked for maximum response values on an iteration run.
P(MBAR*NBAR)	Pressure at each spatial point, psi.
PI	Constant, equal to π.
PIMA(MBAR)	Constants associated with the equation of motion and Simpson's Rule. Gamma-direction, $in^2/lb\text{-}sec^2$.
PINA(NBAR)	Same as PIMA, only in the beta-direction.
*PRINT	Output frequency - integration steps per printout.
PP(NBAR,MBAR)	Pressure coefficients for nonuniform load, psi. Not used in NOVA.
PRES(3*MG*MB)	Working array in RELAXP, dimensionless.
PX(3*MG*MB)	Working array in RELAXP, dimensionless.
RHO	Density of panel, $lb\text{-}sec^2/in^4$.
*RHOM(NL)	Density of layer, $lb\text{-}sec^2/in^4$.
RRES(3*MG*MB)	Working array in RELAXP, dimensionless.
*SAC(NL)	Compressive yield stresses for metal material, compressive ultimate stress for plastic material, psi.
*SAT(NL)	Tensile yield stress for metal meterial, tensile ultimate stress for plastic material, psi.
*SIGO	Yield stress for elastic-plastic option, psi.
SIGO2	Constant, equal to SIGO squared, lb^2/in^4.
SIGX(3*MG*MB)	Working array in RELAXP, dimensionless.
SINB(MB*NBAR)	Sines of beta functions, $\sin(2n\beta_j)$.
SING(MG*MBAR)	Sines of gamma functions, $\sin(2n\gamma_i)$.
SIN2B(MB*NBAR)	Sines of beta functions, $\sin((n-1)\beta_j)$.
SIN2G(MG*MBAR)	Sines of gamma functions, $\sin((m-1)\gamma_i)$.

SKTT(LMAX)	Stress component, $\sigma^b_{\theta\theta}$, psi.
SKXT(LMAX)	Stress component, $\sigma^b_{x\theta}$, psi.
SKXX(LMAX)	Stress component, σ^b_{xx}, psi.
SMAX	Critical response compared with allowable, dimensionless.
STT(LMAX)	Stress component, $\sigma^m_{\theta\theta}$, psi.
SXT(LMAX)	Stress component, $\sigma^m_{x\theta}$, psi.
SXX(LMAX)	Stress component, σ^m_{xx}, psi.
*THETA0	Total angle subtended by cylindrical panel, θ_0, deg, or width of flat panel, b, in.
*THNU(NL)	Poisson's ratio in the theta-direction, ν_θ, dimensionless.
TMAX	Time at which SMAX occurs, sec.
*TNU	Poisson's ratio for elastic-plastic option.
*TSTOP	Integration stop time, sec.
U(MBAR*NBAR)	Value of U, dimensionless.
UB(MBAR*NBAR)	Value of U_β, dimensionless.
UG(MBAR*NBAR)	Value of U_γ, dimensionless.
UU(MB,MG)	Displacement coefficient, U_{mn}, dimensionless.
U1(MB,MG)	Displacement coefficients, U_{mn}, representing the preblast static conditions, dimensionless.
V(MBAR*NBAR)	Value of V, dimensionless.
VB(MBAR*NBAR)	Value of V_β, dimensionless.
VG(MBAR*NBAR)	Value of V_γ, dimensionless.
VV(MB,MG)	Displacement coefficients, V_{mn}, dimensionless.
VXO(3*MG*MB)	Initial velocity coefficients, always zero in NOVA, 1/sec.

V1(MB,MG)	Displacement coefficients, V_{mn}, representing the preblast static condition, dimensionless.
W(MBAR*NBAR)	Value of W, dimensionless.
WB(MBAR*NBAR)	Value of W_{β}, dimensionless.
WBB(MBAR*NBAR)	Value of $W_{\beta\beta}$, dimensionless.
WG(MBAR*NBAR)	Value of W_{γ}, dimensionless.
WGB(MBAR*NBAR)	Value of $W_{\gamma\beta}$, dimensionless.
WGG(MBAR*NBAR)	Value of $W_{\gamma\gamma}$, dimensionless.
WW(MB,MG)	Displacement coefficients, W_{mn}, dimensionless.
W1(MB,MG)	Displacement coefficients, W_{mn}, representing the preblast static conditions, dimensionless.
XB(NBAR)	Integration positions in the beta-direction, inches for flat panel, degrees for curved panel.
XG(MBAR)	Integration positions in the gamma-direction, inches.
XJ	Constant, J, equal to $180/\theta_0$ (dimensionless) for curved panel and π/b (inches) for flat panel.
XJ2	Constant, J^2
XJ3	Constant, J/L.
XJ4	Constant, 2J.
XJ5	Constant, 2J/L.
XKTT	Temporary value of strain, $\varepsilon^b_{\theta\theta}$, in/in.
XKXT	Temporary value of strain, $\varepsilon^b_{x\theta}$, in/in.
XKXX	Temporary value of strain, ε^b_{xx}, in/in.
XL	Constant, ℓ/π, for flat panel (inches), $\ell/\pi a$ for curved panel (dimensionless).
*XLP	Length of panel, ℓ, inches.
XLP1	Constant, $2L^2R$.

XLP2	Constant, 2LR
XL1	Constant, 1/L.
XL2	Constant, L^2.
XL3	Constant, 2/L.
XL4	Constant, $2L^2$.
XL5	Constant, $2L^2R$.
XL7	Constant, $1/L^2$.
XRES(3*MG*MB)	Working array in RELAXP, dimensionless.
XX(3*MB*MG)	Array composed of UU, VV, and WW, dimensionless.
*XXNU(NL)	Poisson's ratio in the x-direction, ν_x, dimensionless.
XX1(3*MG*MB)	Working array in RELAXP, dimensionless.
X1A(MBAR*NBAR)	Strain component, ε^m_{xx}, in/in.
X2A(MBAR*NBAR)	Strain component, $\varepsilon^m_{\theta\theta}$, in/in.
X3A(MBAR*NBAR)	Strain component, $\varepsilon^m_{x\theta}$, in/in.
X4A(MBAR*NBAR)	Strain component, ε^b_{xx}, in/in.
X5A(MBAR*NBAR)	Strain component, $\varepsilon^b_{\theta\theta}$, in/in.
X6A(MBAR*NBAR)	Strain component, $\varepsilon^b_{x\theta}$, in/in.
YY(3*MG*MB)	Array composed of acceleration coefficients, $\ddot{U}_{mn}$, $\ddot{V}_{mn}$, $\ddot{W}_{mn}$, 1/sec^2.
ZA(2)	ZB normalized with a, ZB/a, inches for flat plate, dimensionless for a curved panel.
ZB(2)	z positions for determining critical strains for the elastic-plastic option, in.
ZC(2*NL)	z positions for determining critical strains for the elastic option, in.

ZF(6)	ZH normalized with a, ZH/a, inches for a flat plate, dimensionless for a curved panel.
ZG(6)	Gaussian station squared, ξ_i^2, dimensionless.
ZH(6)	z coordinates corresponding to the Gaussian integration points through the thickness for the elastic-plastic option, in.

The following is a list of dimensioned variables used only in subroutine SIGMA in conjunction with the elastic-plastic model in DEPROP:

AKTT (LMAX)	ETT1 (LMAX)
AKXT (LMAX)	EXT1 (LMAX)
AKXX (LMAX)	EXX1 (LMAX)
ALTT (LMAX)	SIGTT1 (LMAX)
ALXT (LMAX)	SIGXT1 (LMAX)
ALXX (LMAX)	SIGXX1 (LMAX)
BE1 (LMAX)	SIKTT1 (LMAX)
BE2 (LMAX)	SIKXT1 (LMAX)
BE3 (LMAX)	SIKXX1 (LMAX)
BE4 (LMAX)	TTNU (LMAX)
BE5 (LMAX)	XKTT1 (LMAX)
BE6 (LMAX)	XKXT1 (LMAX)
EPB (LMAX)	XKXX1 (LMAX)

6.3 PROGRAM INPUT DATA SETS

The assessment by NOVA of the vulnerability of aircraft to overpressure effects depends, in part, on the selection of appropriate burst orientations and structural elements. Those structural elements, in turn, need to be converted into models which can be analyzed by DEPROB and DEPROP. A few samples of this technique are presented in NOVA-1, Volume 2 (ref. 50). An attempt has also been made throughout this document, and particularly this section, to assist the analyst in the preparation of appropriate data for NOVA, DEPROB, and DEPROP.

The input data sets for NOVA, DEPROB and DEPROP are specified in groups. Each group begins on a separate data card; however, additional cards may be required. The format corresponding to each data group is given in parentheses and is always in fields of 12. Each parameter in the data set is described and its units specified; also, the associated variable name is given. Blank cards are used by the program to indicate the beginning of the next data group or to initiate a logical branch. Columns 73 through 80 may be useful to label the cards in the data sets to facilitate assembly of the card deck and recognition of the variables in the data sets.

6.3.1 NOVA Input Data Set

The NOVA routine is the master routine which directs the overall program flow and provides the preblast and blast-induced pressures. The NOVA input data set includes data necessary for the performance of these functions. The data for DEPROB and DEPROP are included in Group 31 of the NOVA input data set as appropriate. The following comments apply to the preparation of the NOVA data:

Group 9 specifies which ground reflection model is to be used, if any. If ground reflection is not deemed significant for the problem of interest (KGRD=0), or if the analytical curve fit model is used (KB=2), the REFRA data tape is not required. Otherwise, it is required; and unless the run is merely a response run (KDAM=2), the range iteration must be restricted to constant altitude by specifying KALT=1. When an iteration is constrained to one altitude it means that the direction

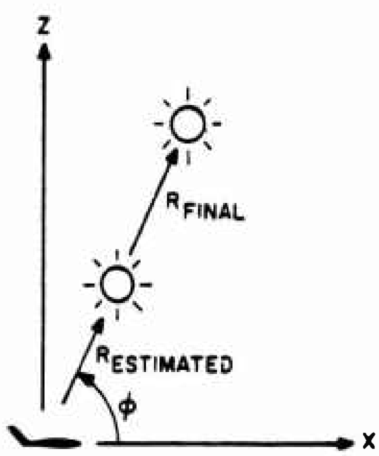
cosines associated with that orientation will not remain constant, as shown in figure 76. Note that there also then exists a minimum range, R_{MIN}, except for orientations where burst and aircraft are at the same altitude. Twenty-two nominal burst orientations are presented in table 22 and figure 76. For the example shown in figure 76, the direction cosines are related to ϕ by:

$$XOSRO = -\cos\phi$$

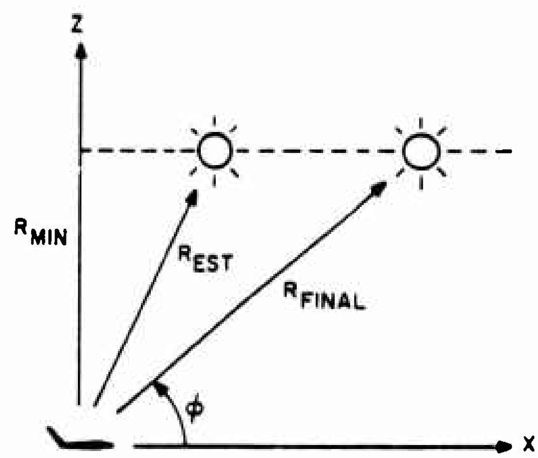
$$YOSRO = 0$$

$$ZOSRO = -\cos\left(\frac{\pi}{2} - \phi\right)$$

Groups 12-24 describe the aircraft geometry. Note that the appropriate coordinate system is the aircraft axis system (AAS) which is centered at the aircraft center of gravity (table 21 and figure 75). Groups 12-20 define the geometries of the lifting surfaces of the aircraft for the aerodynamic routines. If a lifting surface has a straight leading edge, then the coordinates of only two points are needed for complete definition of that leading edge. If the leading edge has n straight-line segments, then n+1 points are needed. The first point for



(a) Slant Range Iteration. (KALT=0)



(b) Constant Altitude Iteration. (KALT=1)

Figure 76. Examples of the Two Range Iteration Techniques used in NOVA

Table 22

DIRECTION COSINES DEFINING ORIENTATIONS

Orientation Number	†Direction Cosines XOSRO	YOSRO	ZOSRO
1	-0.8660254	0.0	0.5
2	-0.5	0.0	0.8660254
3	0.0	0.0	1.0
4	0.5	0.0	0.8660254
5	0.8660254	0.0	0.5
6	1.0	0.0	0.0
7	0.8660254	0.0	-0.5
8	0.5	0.0	-0.8660254
9	0.0	0.0	-1.0
10	-0.5	0.0	-0.8660254
11	-0.8660254	0.0	-0.5
12	-1.0	0.0	0.0
13	-0.8660254	-0.5	0.0
14	-0.5	-0.8660254	0.0
15	0.0	-1.0	0.0
16	0.5	-0.8660254	0.0
17	0.8660254	-0.5	0.0
18	0.0	-0.5	0.8660254
19	0.0	-0.8660254	0.5
20	0.0	-0.8660254	-0.5
21	0.0	-0.5	-0.8660254

† The direction cosines (XOSRO, YOSRO, ZOSRO) locate the aircraft with respect to the nuclear burst in the earth-fixed axis system (EFAS).

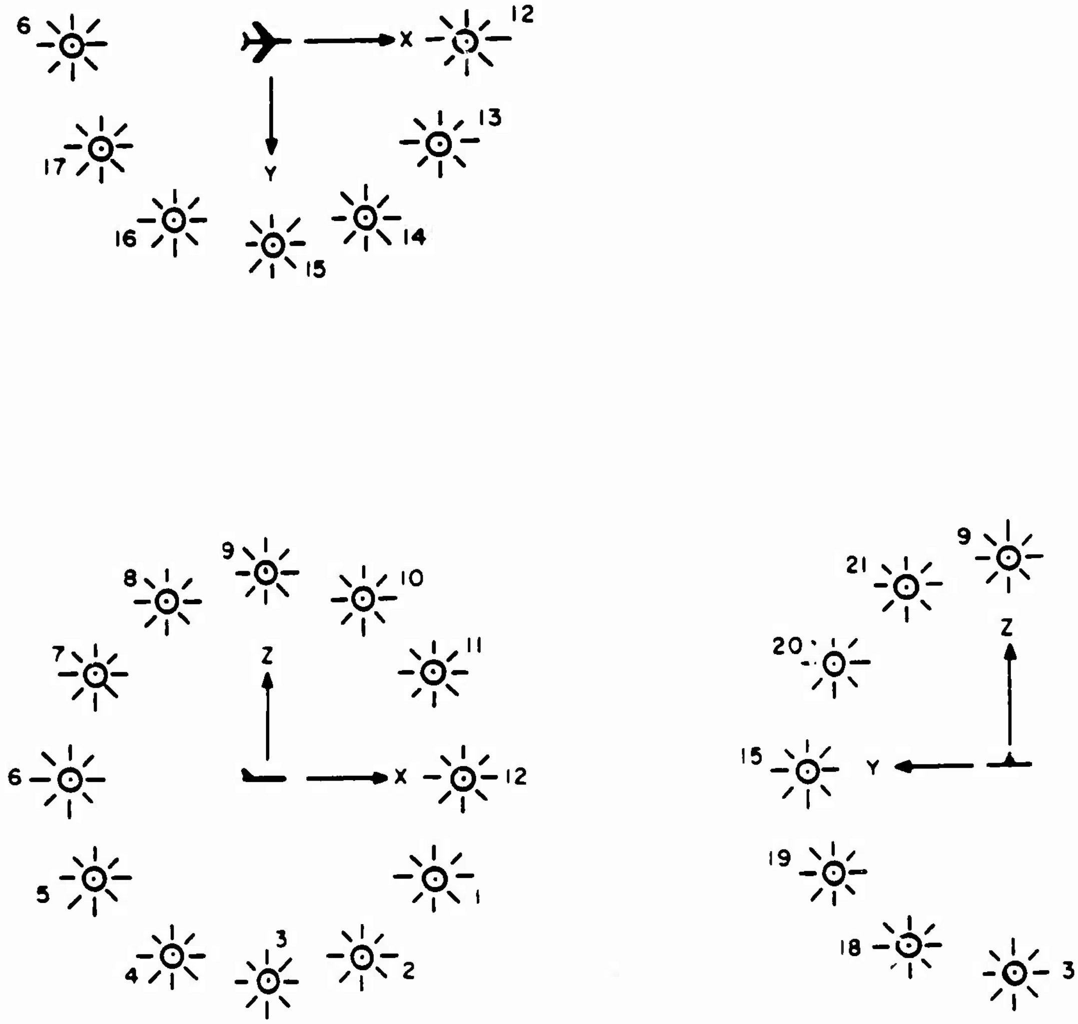


Figure 77. Nuclear Burst Orientations, Horizontal
Aircraft Axis System

both the leading and trailing edges of the wing and horizontal tail should be on the aircraft centerline, and the last point should be at the tip. For the vertical tail leading edge, the first point should be at the intersection of the leading edge with the fuselage surface and the last point should be at the tip. The first point for the trailing edge of the vertical tail should have a z coordinate less than or equal to the z coordinate of the first point for the leading edge, and the last point should be at the tip.

Groups 21 through 24 define the fuselage geometry. As a minimum, fuselage sections should be located as follows:

1. At the center of each panel, stringer or longeron being analyzed
2. At each frame or bulkhead being analyzed
3. At any radome section which is being analyzed

Regardless of the number of fuselage structural elements being analyzed, a sufficient number of fuselage stations must be selected to define the fuselage outline reasonably well. The radius for each equivalent fuselage section is determined by considering a circular cross section of equal area to the actual cross section at that station. These data are not particularly critical; therefore, sections may be located near, rather than exactly at, the above positions, and the radii may be found approximately.

Group 28 locates the center of the structural element (panel, stringer, or longeron) on the circumference of the equivalent, circular section for the fuselage. This is the point at which the pressures are applied (see fig. 19).

The NOVA input data are defined by the following groups:

Group 1: (40A2) Title

Description of aircraft, date, etc. Free field. Can be left blank. (TITLE)

Group 2: (2I12) INOUT, NDBUG

Program output option code (INOUT):
- 0, do not print out description of input data
- 1, print out description of input data.

Debugging option code (NDBUG):
- 0, no additional debugging information printed out - normal option.
- 1, most additional information printed out
- 2, all additional information printed out - can be voluminous.

Group 3: (4F12.1) ALT, VEL, WKT, HG

Aircraft altitude (ALT), ft
Aircraft velocity (VEL), ft/sec
Weapon yield (WKT), KT
Height of ground above sea level (HG), ft

Group 4: (4F12.1) ALFAA, HTINC, BAF, XBF

Aircraft angle of attack (ALFAA), rad
Horizontal tail incidence angle (HTINC), rad
Bend angle (β) of the fuselage (fig. 26) (BAF), rad
X coordinate (Aircraft Axis System) of fuselage station at which bend angle (β) occurs (fig. 26) (XBF), in

Groups 5-7 provide data for the desired nuclear burst orientations, and are repeated until data for all desired orientations have been provided. The last value of NORMAX in Group 5 must be the largest value. Refer to table 22 for the direction cosines which define the orientations (fig. 77) provided in the program.

Group 5: (2I12) NOR, NORMAX

First orientation to be considered (NOR)
Last orientation to be considered (NORMAX)

Note: Program considers all intermediate orientations. For KALT=1, (Group 10), orientation numbers 3 and 9 are not permitted for iteration runs (KDAM=0,1).

If NORMAX < 22, skip to Group 7.

Group 6 provides the capability for reading in direction cosines (EFAS) for orientations other than the 21 provided in the program. Repeat Group 6 for N = N1, NORMAX, where N1 is the larger of NOR and 22.

Group 6: (3F12.1) (XOSRO(N), YOSRO(N), ZOSRO(N)), N=N1, NORMAX

X direction cosine (XOSRO(N))
Y direction cosine (YOSRO(N))
Z direction cosine (ZOSRO(N))

Group 7: (6F12.1) (REST(N), N=NOR, NORMAX)

Range at which response is desired or estimated range at which desired response occurs (REST(N)), ft

Group 8:

Blank card.

Group 9: (2I12) KB, KGRD

Control constant for ground reflection model (KB):
- 1, REFRA tape, based on REFLECT code.
- 2, Analytical model

Control constant for ground reflection (KGRD)
- 0, no ground reflection in model
- 1, ground reflection included in model

Note: For KGRD=0, it makes no difference whether KB=1 or 2.

Group 10: (2I12) KDAM, KALT

Range iteration/damage code (KDAM)
- 0, iterate to determine range at which permanent damage first occurs
- 1, iterate to determine range at which catastrophic damage occurs
- 2, determine response only at specified range

Constant altitude code (KALT)
- 0, no restriction on iteration.
- 1, iteration is restricted to constant altitude.

Note: KALT is not necessary for KDAM=2. Otherwise KALT must be 1 if KB is 1 and KGRD is also 1.

If KDAM = 2, skip to Group 12.

Group 11: (1F12.1) PDAM

Probability of exceeding specified damage level, m, expressed as a fraction (0<m<1) (PDAM), dimensionless (Use 0.5 to neutralize probability of damage calculation)

Group 12: (2I12) NLEW, NTEW

Number of points used to define the leading edge of the wing (NLEW) (Set = 0 if no model on wing)

Number of points used to define the trailing edge of the wing (NTEW) (Set = 0 if no model on wing)

<u>If NLEW = 0, skip to Group 15.</u>

Group 13: (2F12.1) (XLEW(N), YLEW(N)), N=1, NLEW

X coordinate (AAS) of point used to define wing leading edge (XLEW(N)), in

Y coordinate (AAS) of point used to define wing leading edge (YLEW(N)), in

Group 14: (2F12.1) (XTEW(N), YTEW(N)) N=1, NTEW

X coordinate (AAS) of point used to define wing trailing edge (XTEW(N)), in

Y coordinate (AAS) of point used to define wing trailing edge (YTEW(N)), in

Group 15: (2I12) NLEHT, NTEHT

Number of points used to define the leading edge of the horizontal tail (NLEHT) (Set = 0 if model is not on horizontal tail)

Number of points used to define the trailing edge of the horizontal tail (NTEHT) (Set = 0 if model is not on horizontal tail)

<u>If NLEHT = 0, skip to Group 18.</u>

Group 16: (2F12.1) (XLEHT(N), YLEHT(N)), N=1, NLEHT

X coordinate (AAS) of point used to define horizontal tail leading edge (XLEHT(N)), in

Y coordinate (AAS) of point used to define horizontal tail leading edge (YLEHT(N)), in

Group 17: (2F12.1) (XTEHT(N), YTEHT(N)), N=1, NTEHT

X coordinate (AAS) of point used to define horizontal tail trailing edge (XTEHT(N)), in

Y coordinate (AAS) of point used to define horizontal tail trailing edge (YTEHT(N)), in

Group 18: (2I12) NLEVT, NTEVT

Number of points used to define the leading edge of the vertical tail (NLEVT) (Set = 0 if model is not on vertical tail

Number of points used to define the trailing edge of the vertical tail (NTEVT) (Set = 0 if model is not on vertical tail)

If NLEVT = 0, skip to Group 21.

Group 19: (2F12.1) (XLEVT(N), ZLEVT(N)), N=1, NLEVT

X coordinate (AAS) of point used to define vertical tail leading edge (XLEVT(N)), in

Z coordinate (AAS) of point used to define vertical tail leading edge (ZLEVT(N)), in

Group 20: (2F12.1) (XTEVT(N), ZTEVT(N)), N=1, NTEVT

X coordinate (AAS) of point used to define vertical tail trailing edge (XTEVT(N)), in

Z coordinate (AAS) o point used to define vertical tail trailing edge (ZTEVT(N)), in

Group 21: (1I12) (NFS)

Number of fuselage sections used to describe fuselage geometry (NFS)(Set = 0 if model is not on fuselage)

If NFS = 0, skip to Group 25.

Group 22: (2F12.1) XNOSE, XTAIL

X coordinate (AAS) of nose of fuselage (XNOSE), in

X coordinate (AAS) of tail of fuselage (XTAIL), in

Group 23: (2F12.1) YF, ZF

Y coordinate (AAS) of center of fuselage (will ordinarily be 0.0; it is included to accommodate external stores or nacelles) (YF), in

Z coordinate (AAS) of fuselage axis (ZF), in

Group 24: (2F12.1) (XB(N), RF(N)), N=1, NFS

X coordinate (AAS) of fuselage section (XB(N)), in

Radius of equivalent fuselage (RF(N)), in

Groups 25-31 provide data for a structural element and are repeated until all structural element data have been provided.

Group 25: (3I12) ICOMP, KTYPE, IUL

Code designating aircraft component on which the structural element is located (ICOMP)
1, Wing
2, Fuselage
3, Horizontal tail
4, Vertical tail

Code designating structural type (KTYPE)
1, Single-layer metal panel
2, Single-layer plastic panel
3, Honeycomb metal panel
4, Honeycomb plastic panel
5, Multilayer plastic panel
6, Metal stringer or longeron
7, Metal frame
8, Free metal ring
9, Free plastic ring, e.g., a radome
10, Metal rib

Code designating side of lifting surface being considered (IUL)
1, Upper surface, or right side of vertical tail
2, Lower surface, or left side of vertical tail

Note: Omit IUL when structural element is located on fuselage (ICOMP = 2) or for rib elements (KTYPE=10).

If ICOMP=2, skip to Group 27.

Group 26: (3F12.1) XP, YP, ZP

X coordinate (AAS) of point at which pressure is desired (middle of panel, stringer, longeron; rib station) (XP), in

Y coordinate (AAS) of point at which pressure is desired (middle of panel, stringer, longeron; rib station), (YP), in

Z coordinate (AAS) of point at which pressure is desired (middle of panel, stringer, longeron; rib station) (ZP), in

<u>For KTYPE<10, skip to Group 30.</u>

<u>For KTYPE=10, skip to Group 31.</u>

Group 27: (1I12) NFP

The number of the fuselage section at which pressures are desired (that is, the section at which the structural element is located) (NFP)

<u>If the structural element is a metal frame or a ring (KTYPE > 6), skip to Group 29.</u>

Group 28: (1F12.1) THETAR

Angular location of the center of the structural element (panel, stringer, or longeron) on the circumference of the equivalent, circular section for the fuselage (see fig. 19). This is the point at which the pressures are applied ($-\pi<\theta\leq\pi$) (THETAR), rad

Group 29: (1F12.1) DRDX

Rate of change of radius of equivalent body cross section with respect to x (Aircraft Axis System) at the fuselage station where the pressures are desired (DRDX), dimensionless

Group 30: (1F12.1) PINT

Internal pressurization. Difference between the internal pressure and external ambient pressure (p_i-p_e) (PINT), lbs/in^2.

Group 31:

Group 31 consists of the DEPROB (KTYPE > 5) and the DEPROP (KTYPE < 6) data sets for the structural elements being analyzed.

Group 32:

A blank card is placed after the last data set in Group 31 to end program execution.

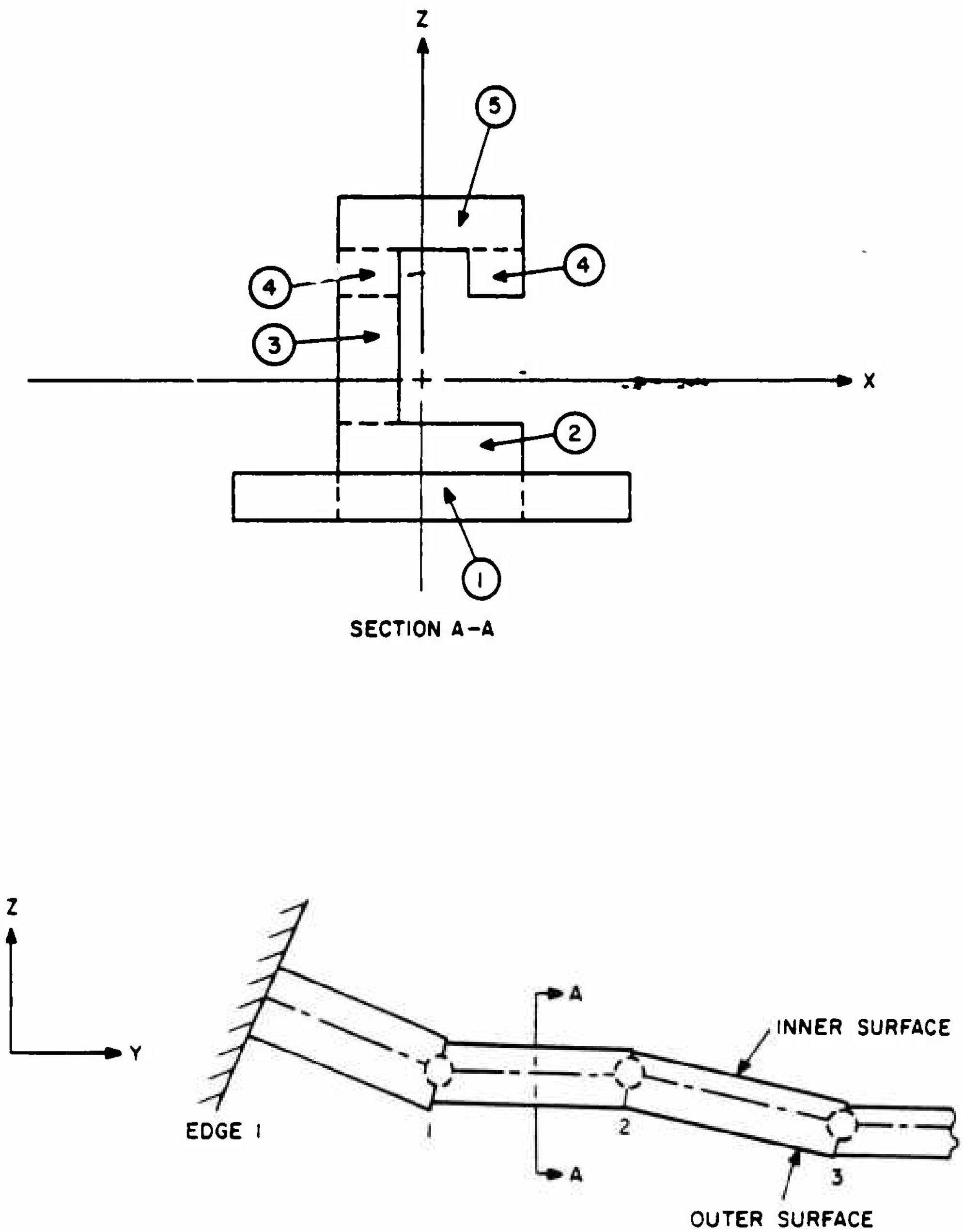
6.3.2 DEPROB Input Data Set

The DEPROB routine calculates the response of a beam to preblast and blast-induced pressures. The beam can be of arbitrary cross section and shape, both of which can vary spanwise along the beam. Any combination of clamped, simply supported or free boundary conditions is possible. Also treated are complete (free) rings, either circular or not, and end loaded beams (ribs) characterized by a sliding clamp condition. Panels exhibiting large aspect ratio can also often be analyzed by only considering a strip in the short direction; however, it is up to the analyst to verify the validity of such an approximation.

In general, the analyst must model the structural element by selecting a bar-mass representation, as indicated in figure 28, and dividing the cross section into regular layers as indicated in figures 29 and 78.

The paragraphs which follow amplify the specific input instructions put forth later in this section. The theoretical discussion in section 4.1 should also be consulted, and certain input parameters should be compared with the maximum allowable dimensions as delineated in table 18.

Group 1 describes the beam in general terms. If the structural element is circular in shape (KEYRG=1), the program will automatically evenly space the masses. The end constraints are specified by KEYB1 and KEYB2. Any combination is theoretically possible; but because preblast loading necessitates a complicated static solution, only the following seven combinations are permissible for elements experiencing preload:



Notes:
a) 1 indicates layer number 1, etc.
b) 1 indicates mass number 1, etc.
c) inner and outer surfaces are defined for KIS=1.

Figure 78. Bar-Mass and Rectangular Layer Model of Beam Element

	1st End	(KEYB1)	2nd End	(KEYB2)
1)	Clamped	(2)	Clamped	(2)
2)	Clamped	(2)	Free	(4)
3)	Clamped	(2)	Symmetric	(5)
4)	Clamped	(2)	Simply Supported	(3)
5)	Simply Supported	(3)	Simply Supported	(3)
6)	Simply Supported	(3)	Symmetric	(5)
7)	Free Ring	(1)	Free Ring	(1)

The symmetric option, where only half of the structure is treated, is appropriate for structures exhibiting both geometrical and loading (preblast and postblast) symmetry. Special caution should be exercised in modeling frames since the burst orientation will not, in general, be in a position to induce a symmetrical load. Radomes (free rings) do not attempt to take advantage of symmetry for this reason, although it should be noted that the bar-mass representation selected by the analyst must be symmetrically spaced about the z-axis. (fig. 34(e)).

It should be noted that the boundary code 2 (KEYB1,KEYB2=2) actually represents a clamped-sliding boundary for rib elements (KTYPE=10). In all other cases it represents an ideal clamp.

The parameter KIS removes all ambiguity associated with which surface of the beam element is loaded. Such ambiguities arise when the spanwise shape exhibits curve reversal. It is assumed that the outer surface always receives the blast loading and hence, KIS=1 represents normal loading (see fig. 78). Care should always be taken, however, to assign the correct loading code, KIS, to curved elements and those with nonsymmetrical nonuniform cross section. The exception to this involves rings and ribs (KTYPE=8,9 and 10) where the parameter KIS is not needed.

The boundary fixity, or support code, of the outstanding leg of an element must also be specified in the Group 1 input data. In figure 78, the outstanding leg is segment 5, and the appropriate support code is 2, because segment 5 is supported on both ends by the two parts of segment 4. If the right hand portion of segment 4 were absent, the support code would be 1. In practice, if there is a bulb present, the

support code should be 2. In addition, a small bulb can be accounted for in the layer modeling by combining its area with that of an adjoining layer.

Group 2 assigns the number of masses, layers and flanges to the model of the structural element. The model consists of discrete masses interconnected by weightless bars, with cross sections which may consist of several layers. The DEPROB routine represents each layer by several flanges. The modeling accuracy increases when the number of masses, layers, or flanges is increased. For a straight beam element, about 14 masses (7 for a symmetrical case) are usually required to adequately represent the beam; a curved beam requires up to 20 for a 180 degree arc; a complete ring requires approximately 40 (the maximum number the program is dimensioned for). The maximum number of flanges allowed in any layer (NX) must be an even number and six is recommended, except for a cross section with more than three layers when 4 is suggested. The total number in the cross section must not exceed 20. As explained in section 4.1.4, fewer flanges are assigned to some layers.

Groups 5-7 locate the element in the local coordinate system (LAS) described in table 21. The location and orientation of the y-z coordinate frame is unimportant -- only relative positions are relevant, except in the case of frames and radomes, as noted. In general, even spacing of masses is recommended except at the ends where the spacings indicated in figure 34 are suggested.

Groups 8-11 provide for external elastic supporting elements, fixed to the frame (or whatever element is being analyzed by DEPROB) at one or more mass point locations.

The parameter, WT, specified in Group 14, represents an effective width over which the pressure acts. This adjustment takes into account the skin area subjected to loading but not included in the cross section model (see discussion of Group 16). For a stringer or longeron, WT should be the stringer or longeron spacing; for a frame, the frame spacing is appropriate; for a radome ring, the width should be the same as the width of the structural ring used, presumably 1 inch. For rib

elements, WT should represent the average spacing, d, between webs, as indicated in figure 79. It is assumed in this case that a strip of unit width situated between lightening holes and running the depth of the web is being analyzed, where the external pressure load is equally distributed on either end of the column.

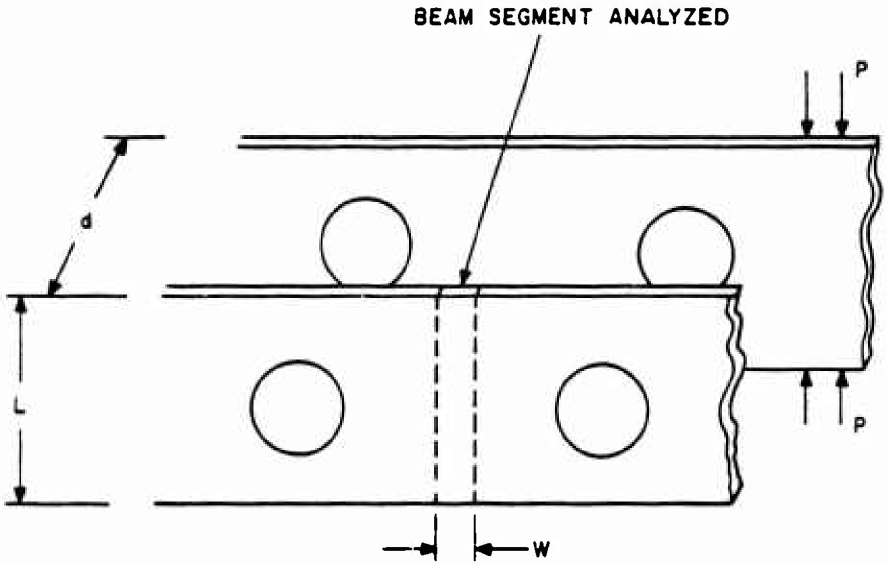


Figure 79. Rib Element Loading Definition

Groups 15 and 16 describe the cross section geometry at each mass point unless the beam is uniform, in which case only one description is required. The analyst divides the arbitrary cross section into rectangular segments or layers as indicated in figure 78. The effective skin (layer 1 in fig. 78), acting with the stringer or longeron, must also be determined. There are many approaches available in the literature for determining the amount of effective skin. A simple approach is suggested below; however, the user is free to exercise his own preference in the determination of effective skin. The suggested approach is as follows:

$$w = 1.70\, t \sqrt{\frac{E}{f_y}} \qquad (148)$$

where

w - effective skin width, in.

t - skin thickness, in.

E - Young's Modulus for the skin material, lbs/in^2

f_y - yield stress for the skin material, lbs/in^2

The appropriate width for layer 4 in figure 78 is the combined width of the two segments labeled "4".

Each layer or segment of the original cross section can have a different stress-strain curve, which may be different in tension than in compression. This capability allows the analyst to consider nonhomogeneous cross sections. The analyst must define the stress-strain curve for the material in each layer by a series of straight lines (figs. 30 and 31). The points at which these straight lines join are referred to as break points, and the appropriate data are provided by Groups 17-20. As noted, the elastic slope must be the same in tension and compression, and the total number of distinct stress-strain slopes (excluding zero slope) must not exceed five. The first break point is taken to represent yielding for metals (ultimate for plastic) and the last break point represents rupture conditions.

Group 21 provides the initial imperfection necessary to initiate rib buckling, unless already incorporated into the spanwise shape in Group 6. Without an imperfection, the end loaded element cannot displace laterally. The parameter AMP represents the amplitude δ of an initial 1 - cosine deflection shape imposed on an otherwise straight beam element:

$$\Delta w = \frac{\delta}{2}\left[1 - \cos\frac{(2\pi y)}{L}\right] \qquad (149)$$

Finally, Group 22 provides the integration time increment, the response time and the printout interval. If a zero time increment is specified, the program computes the largest Δt which in most cases will give a stable solution. One exception may be initially curved elements experiencing "snap-through" or rib buckling where a smaller Δt and a larger response time may be required.

Although the stop time can vary a great deal, the total number of integration steps to capture peak response will roughly be between 400-1000. Buckling situations (curved beams, ribs, etc.) may require considerably more. A printout frequency of once every 20 steps is usually adequate for monitoring the response time history; a frequency of 100 is probably more appropriate for the buckling situations.

The DEPROB input data are defined by the following groups.

Group 1: (6I12) KEYRG, KEYB1, KEYB2, KUNF, KIS, KSUP

Structural shape code (KEYRG)

1, structure is circular in shape, but not necessarily an entire ring. Polar coordinates are used to define ends of beam, if necessary. Program evenly spaces mass points.

2, rectilinear coordinates are used to specify the center of the cross section for each mass point.

Boundary condition code, first end of beam (KEYB1)

1, complete ring, no supports at either end (KTYPE=8 or 9). KEYB2 must also be 1 for this case.

2, clamped (clamped-sliding for KTYPE=10)

3, simply supported

4, free (as in a cantilevered or free-free situation)

Boundary condition code, second end of beam (KEYB2)

1, complete ring, no supports at either end (KTYPE=8 or 9).
2, clamped (clamped-sliding for KTYPE=10)
3, simply supported
4, free (as in a cantilevered or free-free situation)
5, symmetry is assumed, second end of beam is specified as point of symmetry

Cross section uniformity code (KUNF)

0, cross section is not uniform spanwise along the structure
1, cross section is uniform spanwise along the structure

Outer surface definition code (KIS)

1, outer surface of cross section is defined as being on the right when proceeding spanwise from the first end to the second end. See fig. 78.

2, outer surface is defined just opposite to that above, i.e., outer surface is on left.

Note: Net positive pressure loading is always applied to "outer" surface. KIS is not needed for KTYPE=8, 9 or 10

Support code for outstanding (inner) leg (KSUP)
0, no outstanding leg
1, outstanding leg supported at one end
2, outstanding leg supported at both ends

Note: KSUP is not needed if KDAM>0 or if KTYPE>7)

Group 2: (3I12) N, NL, NX

Number of masses in the model. (For symmetric cases, only half of the structure is modeled.) Must be an even number for complete rings (KTYPE=8 or 9). (N)

Number of layers in the cross section of the structural element. (NL)

Maximum number of flanges allowed in a layer. Must be an even number. (NX)

If KEYRG=2 and KTYPE=6,7 or 10, skip to Group 5.

If KEYRG=2 and KTYPE=8 or 9, skip to Group 6.

Group 3: (F12.1) BIGR3

Radius to the center of the ring cross section, in. (BIGR3)

If KTYPE=8 or 9, skip to Group 8.

Group 4: (2F12.1) THETA1, THETA2

Angular position of first end of beam, rad. (THETA1)
Angular position of second end of beam (or point of symmetry) rad. (THETA2)

Note: The angular position is specified with respect to the local axis system (LAS) as follows:

0.0	-z direction
$\pi/2$	+y direction
π	+z direction

Skip to Group 8.

Note: The y and z coordinates (LAS) in Groups 5, 6, and 7 are to be specified at the center of the cross section.

Group 5: (2F12.1) V1, W1

Y coordinate (LAS) of first end of beam, in. (V1)

Z coordinate (LAS) of first end of beam, in. (W1)

Group 6: (2F12.1) (V(I), W(I), I=1,N)

Y coordinate (LAS) of mass point, in. (V(I))

Z coordinate (LAS) of mass point, in. (W(I))

If KTYPE=8 or 9, skip Group 7.

Group 7: (2F12.1) V2, W2

Y coordinate (LAS) of second end of beam (or point of symmetry), in. (V2)

Z coordinate (LAS) of second end of beam (or point of symmetry), in. (W2)

Group 8: (I12) NSEL

Number of supporting elastic elements. ($0 \leq NSEL \leq N$) (NSEL)

If NSEL=0, skip to Group 12.

Group 9: (6I12) (NAY(I),I=1,NSEL)

Mass point number corresponding to elastic supporting element. May be listed in any order.

Group 10: (6F12.1) (EI(I), I=1,NSEL)

Elastic stiffness, EI, equal to the product of the modulus of elasticity and the moment of inertia, corresponding to each supporting element, and ordered as in Group 9, lb-in^2.

Group 11: (F12.1) ELL

Length of the supporting element(s), in. (Each is assumed to be the same length.)

Group 12: (6I12) (IPROP(L), L=1, NL)

Material code for layer (IPROP(L))

- 0, stress-strain curve is the same in tension as in compression
- 1, different stress-strain curves will be specified for compression and tension

Group 13: (6F12.1) (RHO(L), L=1,NL)

Mass density of material, lb-sec^2/in^4.

Group 14: (F12.1) WT

Width over which pressure acts, in.

<u>Groups 15-20 specify data for each layer and are to be repeated for L=1,NL</u>

Note: The thickness and width of each layer can vary along the beam for KUNF=0. In this case data must be provided for each end of the beam (unless it is a ring) as well as for each mass point, and the data are entered in the following order: first end, N mass points, second end (or point of symmetry). The parameter N2 is defined as follows:

N2 = 1, uniform beam (KUNF=1)
N, nonuniform beam, complete ring (KUNF=0 and KTYPE=8 or 9)
N+2, nonuniform beam, not a ring (KUNF=0 and KTYPE≠8 or ≠9)

Group 15: (6F12.1) (H(L,I),I=1,N2)

Thickness of the layer at each station, in.

Group 16: (6F12.1) (WR(L,I),I=1,N2)

Width of the layer at each station, in.

Group 17: (I12) NSSC(L)

Number of straight-line segments specified in the representation of the stress-strain curve for compression (NSSC(L))

Group 18: (2F12.1) (STRNA(L,II),STRSO(L,II)) II=1, NSSC(L)

Strain at break point on the stress-strain curve for compression, in/in (STRNA(L,II))

Absolute value of stress at break point on the stress-strain curve for compression, lbs/in^2 (STRSO(L,II))

Note: For KDAM=1, the last break points on the stress-strain curves must correspond to ultimate strain. The program assumes constant stress (zero slope) curve beyond the last break point.

<u>If the tensile and compressive stress-strain curves are the same (IPROP(L) = 0), skip Groups 19 and 20.</u>

Group 19: (I12) (NSSCT(L))

Number of straight-line segments specified in the representation of the stress-strain curve for tension (NSSCT(L))

Group 20: (2F12.1) (STRNAT(L,II), STRSOT(L,II)), II=1, NSSCT(L)

Strain at break point on the stress-strain curve for tension, in/in (STRNAT (L,II))

Stress at break point on the stress-strain curve for tension, lbs/in^2 (STRSOT(L,II)

Note: The slope of the first segment must be the same in both tension and compression)

<u>If KTYPE<10, skip Group 21.</u>

Group 21: (F12.1) AMP

Amplitude of the initial imperfection introduced into the rib element, in. If imperfection is already specified through V and W (Group 6), set equal to 0.0. (AMP)

Group 22: (3F12.1) DELTIM, TSTOP, PRINT

Integration time increment, sec. If DELTIM=0.0, the program determines the time increment required for stability. (DELTIM)

Integration stop time, sec. (TSTOP)

Print frequency (integration steps per printout). If PRINT=0.0, printout of intermediate data will be suppressed. (PRINT)

6.3.3 DEPROP Input Data Set

The DEPROP program calculates the elastic or elastic-plastic response of cylindrical or flat panels to preblast and blast-induced pressures uniformly distributed over the surface. The panel can be single or multilayered, have orthotropic or isotropic material properties, and can have any combination of clamped or simply supported edge conditions. The following paragraphs are intended to amplify the specific input data instructions for using the DEPROP code. All input parameters, where appropriate, should be compared with the maximum dimensions provided for in the program, as delineated in table 19.

Group 1 contains the number of modes to be used in the solution, and the number of integration points to be used. The accuracy of the solution is based on the degree of convergence of stress and strain quantities. These quantities converge less rapidly than the radial displacement. Also, cases involving a clamped edge condition will converge less rapidly than simply supported cases. Since both computer time and accuracy increase with more modes and points, a trade-off usually becomes necessary.

In general, a minimum of nine modes should be used for panel solutions and it is recommended that the maximum of 25 modes be used for clamped panels where edge stresses and strains are important. The program uses modes 1 through MB in the β or θ-direction and 1 through MG in the γ or x-direction. The maximum value that the mode numbers MG and

MB can assume in the program is seven. Spatially, the desired number of integration points (MBAR and NBAR) for a full panel should be approximately four times the maximum mode number used in that direction, plus one. However, when MB or MG is large, this condition may not be satisfied for nonsymmetrical panels, since MBAR and NBAR are dimensioned at 19 in the program (see table 19.) For symmetric solutions (whenever the same edge condition is specified for opposite sides), MBAR (or NBAR) need only be approximately half the value for a full panel since only one half (or one quarter) of the panel is actually analyzed in the solution. For a nonsymmetric condition, MBAR (or NBAR) must be an odd number. For an elastic-plastic solution, a minimum of four integration points through the thickness is recommended, and a maximum of six is provided in the program.

In Group 2, the user is given the option of a purely elastic solution, or an elastic-plastic solution. The elastic-plastic option will tend to be slower and require more computer memory. The second option (elastic-plastic) must be used for metal panel solutions which iterate to a catastrophic damage level.

Groups 3 and 4 provide a mechanism for selecting a maximum of 25 modal combinations from a 7 by 7 combination array (MG=MB=7). Thus, the more significant modal combinations for an optimal solution with respect to accuracy and computer time can be selected and the other combinations eliminated. A general rule of thumb is to eliminate the higher frequency modes which are usually associated with modal combinations having the larger MG+MB values. An example of this would be the selection of MG=MB=7, but <u>eliminating</u> the following 24 combinations:

3,4	4,3	5,3	6,3	7,3
3,5	4,4	5,4	6,4	7,4
3,6	4,5	5,5	6,5	7,5
3,7	4,6	5,6	6,6	7,6
	4,7	5,7	6,7	7,7

The relative importance of each modal combination can be evaluated by examining the response output and comparing the magnitudes of the displacement coefficients.

Group 10 provides the data required for computing allowable stresses for honeycomb panels. The core cell size (DC) is defined as the distance between opposite flat sides of the honeycomb cell.

Group 13 contains the modal components, δ_{mn}, for the initial radial imperfections. The analyst must compute the δ_{mn}'s from measured data using the integration technique applied to Fourier series coefficients. Generally, such data will not be available, and zero values should be specified for the δ_{mn}'s. The capability of considering initial imperfections also enables the analyst to determine the sensitivity of panel response to initial imperfections.

Group 14 provides the integration time increment, the response stop time, and printout interval. If the user specifies a zero time increment, the program computes an appropriate Δt which in most cases will give a stable solution. Because it is approximate, the analyst may want to make comparable runs using different Δt's. In general, an elastic solution which is numerically stable will be accurate. Hence, the optimum Δt is the largest which remains stable. For an elastic-plastic solution, however, the accuracy of the solution may deteriorate slightly as the point at which the solution diverges is approached. Once a time increment is selected, it should be valid for other orientations and moderate changes in response level.

Although the stop time can vary a great deal, the total number of integration steps required to capture peak response will be roughly between 500 and 1500. One exception to this may be a curved panel experiencing "snap-through" buckling, in which case considerably larger response times may be required. A printout frequency of once every 20 steps is usually adequate for monitoring the response time history. The program checks response values every ten time steps.

Group 1: (5I12) MG, MB, MBAR, NBAR, LBAR

Maximum gamma mode number to be used. (MG)

Maximum beta mode number to be used. (MB)

Number of gamma integration points actually used over the portion of the panel analyzed. Must be an odd number for full panel. (MBAR)

Number of beta integration points actually used over the portion of the panel analyzed. Must be an odd number for full panel. (NBAR)

Number of z integration points used through the thickness. (LBAR)
(Not needed for NDERV=1 (See Group 2))

Group 2: (3I12) NPLT, NBND, NDERV

Panel type (NPLT):
- 0, flat panel
- 1, cylindrical panel

Boundary condition code (NBND).

	γ-direction	β-direction
1,	clamped-clamped;	clamped-clamped
2,	simple-simple;	simple-simple
3,	clamped-clamped;	simple-simple
4,	simple-simple;	clamped-clamped
5,	clamped-simple;	clamped-clamped
6,	clamped-clamped;	clamped-simple
7,	clamped-simple;	simple-simple
8,	simple-simple;	clamped-simple
9,	clamped-simple;	clamped-simple

Note: Whenever a clamped-clamped or a simple-simple condition is selected, only half of the panel is analyzed in that direction, and MBAR and NBAR should reflect this.

Response option (NDERV):

- 1, elastic only
- 2, elastic-plastic

(NDERV must be 2 for KTYPE=1 or 3, whenever KDAM=1)

Group 3: (I12) NNOUT

Number of modal combinations to be eliminated from solution (NNOUT).
(0 $\leq$ NNOUT < MG*MB)

If NNOUT=0, skip to Group 5.

Group 4: (2I12) MOUT(I), NOUT(I)

Gamma mode. (MOUT(I))
Beta mode. (NOUT(I))

Repeat Group 4 for I=1, NNOUT. The cards in Group 4 may be arranged in any order.

Group 5: (I12) NL

Number of layers. (NL)
(NL must be 1 for KTYPE=1 or 2, and 3 for KTYPE=3 or 4)

Group 6: (3F12.1) XLP, THETA0, A

Full length of panel, ℓ, in. (XLP)

Full width of flat panel, b (short direction), in. (NPLT=0)

or (THETA0)

Full subtended angle of cylindrical panel, θ_0, deg. (NPLT=1)

Radius of cylindrical panel, in. (A)
(Not needed for NPLT=0)

If NDERV=2, skip to Group 11.

Group 7: (2F12.1) HM(I), RHOM(I)

Distance (h) from the inner panel surface to the outer surface of layer I, in. (HM(I))

Mass density of layer I, lb-sec^2/in^4. (RHOM(I))

Group 8: (5F12.1) EX(I), ET(I), XXNU(I), THNU(I), GXT(I)

Modulus of elasticity in the x-direction, psi. (EX(I))

Modulus of elasticity in the theta-direction, psi. (ET(I))

Poisson's ratio in the x-direction. (XXNU(I))

Poisson's ratio in the theta-direction. (THNU(I))

Shear modulus, psi. (GXT(I))

Group 9: (2F12.1) SAT(I), SAC(I)

Tensile yield stress for metal panels; tensile ultimate stress for plastic panels, psi. (SAT(I))

Absolute value of compressive yield stress for metal panels; absolute value of compressive ultimate stress for plastic panels, psi. (SAC(I))

Repeat Groups 7-9 for I=1, NL.

If KTYPE=1,2, or 5, skip to Group 13.

If KDAM=1 or 2, skip to Group 13.

Group 10: (3F12.1) EC,GC,DC

Core modulus of elasticity parallel to core depth, psi. (EC)

Shear modulus of core, psi. (GC)

Core cell size, in. (DC)

Skip to Group 13.

Group 11: (3F12.1) HM(I), RHOM(I), EM(I)

Distance (h) from inner shell surface in the outer surface of layer I, in. (HM(I))

Mass density of layer I, lb-sec^2/in^4. (RHOM(I))

Modulus of elasticity, psi. (EM(I))

Repeat Group 11 for I=1, NL.

Group 12: (4F12.1) TNU, SIGO, EP, EPSIF

Poisson's ratio. (TNU)

Yield stress for a metal panel, psi. (SIGO)

Strain hardening modulus (E_t), psi. (EP)

Ultimate strain, in/in. (EPSIF)
(Not necessary for KDAM=2)

Group 13: (6F12.1) ((FG(N,M), N=1,MB), M=1,MG)

Modal displacement coefficients for initial radial imperfections, in. (FG(N,M))

Group 14: (3F12.1) DELTIM, TSTOP, PRINT

Integration time increment, sec. If DELTIM=0.0, the program determines the time increment required for stability. (DELTIM)

Integration stop time, sec. (TSTOP)

Print frequency (integration steps per printout). If PRINT=0.0, printout of intermediate data will be suppressed. (PRINT)

6.4 PROGRAM OPERATION AND OUTPUT

The NOVA program is written in FORTRAN-IV and consists of 103 user-supplied routines and approximately 12,000 cards. The program is organized so as to take full advantage of overlaying techniques without sacrificing computer time. This is accomplished by identifying the routines in main execution loops and keeping those routines all in core at the same time.

The code was developed on the Control Data Corporation (CDC) 6600 computer under the SCOPE 3.4.3 operating system. The segmentation loader is utilized due to its flexibility. The overlaying directives are contained within the job control sequence; hence, routines can be reassigned or eliminated from the deck at load time without necessitating changes in the FORTRAN program. The default loader can even be used without any overlaying, but the user must: 1) selectively load

only the routines required and 2) avoid loading DEPROB and DEPROP simultaneously. The program will require approximately 100,000 (octal) additional cells of central memory.

The recommended segmentation layout is presented in figure 80 and tables 23-24. Note that subroutine SIGMA and the associated common block CBLANK are required <u>only</u> for the elastic-plastic option of DEPROP. This option corresponds to selecting NDERV=2 in Group 2, section 6.3.3. This distinction is made because this subroutine and common block require approximately $74,400_8$ cells of memory. Of that amount, only 21000_8 can be overlayed against other routines.

The FTN compiler has been used to compile the code, using options OPT=1 and R=2. Compilation requires $60,000_8$ cells and 121.4 seconds (using fast compile mode (OPT=1) and 147 seconds using fast execution mode (OPT=2).

Without SIGMA and CBLANK, $137,300_8$ cells are required to load and execute; adding them necessitates a total of 213,000 cells. Once the program is executed, an absolute file is created by the segmentation loader which, if saved, will eliminate the need to load the program again, unless changes are made in either the segmentation directives or the program. An example of the required job control sequence is presented in table 25. It is not necessary to preset core to zero prior to execution.

It should be noted that the additional core required for SIGMA and CBLANK is almost entirely due to the length of the common block CBLANK. Additional core can be easily obtained on a CDC 7600 by simply assigning CBLANK to large core memory (LCM) by inserting a LEVEL 2 statement in the program.

When the REFRA near-ground reflection (blast) model is selected and ground reflection is to be included in the analysis (KB=1,KGRD=1), the REFRA data must be available on logical file TAPE10. This data is unformatted (binary) with record type S and block type C. This record type-blocking combination is compatible with SCOPE 3.3 and possesses the important feature that the system copy utility COPYBF can be used with

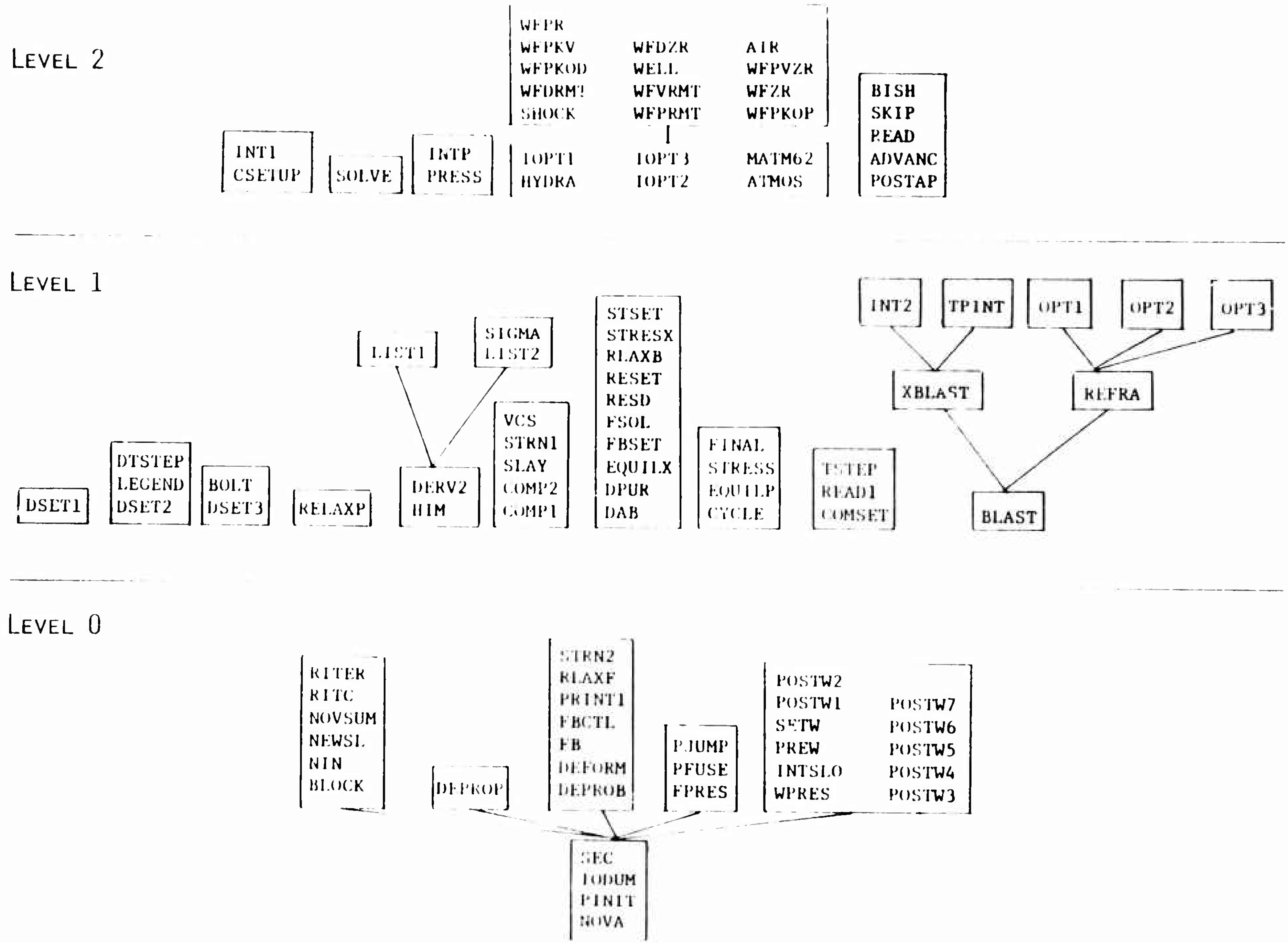


Figure 80. Segmentation Tree Structure of NOVA

TABLE 23. LIST OF COMMON BLOCKS WHICH MUST BE DESIGNATED GLOBAL AND SAVE IN SEGMENTATION

Common block ownership for segmentation:

Routine	Common Blocks	
NOVA	CNOVA	
	DNOVA	
	CTLX	
HYDRA	CONSTC	
	SCALEC	
WPRES	PW1	
REFRA	REFRAC	
DEPROB	BLK2	
	BLK3	
	BLK6	
DEPROP	CBLK1	CBLK7
	CBLK2	CBLK8
	CBLK3	CBLK9
	CBLK4	CBLK10
	CBLK5	CBLK11
	CBLK6	CBLK13
RELAXP	CBLK12	

TABLE 24. SEGMENTATION DIRECTIVES

```
         TREE       NOVA
NOVA     INCLUDE    PINIT,IODUM,SEC
         LEVEL
         TREE       BLOCK
BLOCK    INCLUDE    NIN,NEWSL,NOVSUM,RITC,RITER
         TREE       DEFPROP
         TREE       DEPROB
DEPROB   INCLUDE    DEFORM,FB,FBCTL,PRINT1,RLAXE,STRN2
         TREE       FPRES
FPRES    INCLUDE    PFUSE,PJUMP
         TREE       WPRES
WPRES    INCLUDE    INTSLO,PREW,SETW,POSTW1,POSTW2,POSTW3,POSTW4,POSTW5,P
,OSTW6,POSTW7
         LEVEL
         TREE       DSET1
         TREE       DSET2
DSET2    INCLUDE    LEGEND,DTSTEP
         TREE       DSET3
DSET3    INCLUDE    BOLT
         TREE       RELAXP
         TREE       HIM-(LIST1,LIST2)
HIM      INCLUDE    DERV2
         TREE       COMP1
COMP1    INCLUDE    COMP2,SLAY,STRN1,VCS
         TREE       DAB
DAB      INCLUDE    DPUR,EQUILX,FRSET,FSOL,RESD,RESET,RLAXR,STRESX,STSET
         TREE       CYCLE
CYCLE    INCLUDE    EQUILP,STRESS,FINAL
         TREE       COMSET
COMSET   INCLUDE    READ1,TSTEP
         TREE       BLAST-(XBLAST-(INT2,TPINT),REFRA-(OPT1,OPT2,OPT3))
         LEVEL
         TREE       CSETUP
CSETUP   INCLUDE    INT1
         TREE       SOLVE
         TREE       PRESS
PRESS    INCLUDE    INTP
         TREE       HYDRA-SHOCK
HYDRA    INCLUDE    IOPT1,IOPT2,IOPT3,ATMOS,MATMA2
SHOCK    INCLUDE    WFPRMT,WFPKOD,WFPKV,WFPR,WFPRMT,WFVRMT,WFLL,WFOZR,WFP
,KOP,WF R,WFVZR,AIR
         TREE       POSTAP
POSTAP   INCLUDE    ADVANC,READ,SKIP,RISH
NOVA     GLOBAL     CNOVA,DNOVA,CTLX-SAVE
HYDRA    GLOBAL     CONSTC,SCALEC
WPRES    GLOBAL     PW1-SAVE
REFRA    GLOBAL     REFRAC-SAVE
DEPROF   GLOBAL     BLK2,BLK3,BLK6-SAVE
DEPROB   GLOBAL     CBLK1,CBLK2,CBLK3,CBLK4,CBLK5,CBLK6,CBLK7,CHLK8,CBLK9
,CBLK10,CBLK11,CBLK13-SAVE
RELAXP   GLOBAL     CBLK12-SAVE
         END        NOVA
```

Note: To include subroutine SIGMA, add the following card:
   LIST2   INCLUDE   SIGMA.

TABLE 25. JOB CONTROL SEQUENCE

Job Control Sequence	Comments
MAP,ON. . . .	
REWIND(BIN)	(Object code on file BIN)
ATTACH(TAPE10,....)	(REFRA data on file TAPE10)
FILE,TAPE10,RT=S,BT=C.	
LDSET,FILES=TAPE10.	
LDSET,OMIT=SIGMA.	(Exclude SIGMA from load)
SEGLOAD(B=ABS)	
LOAD(BIN)	
EXECUTE(NOVA)	
REWIND(ABS)	
CATALOG(ABS,....)	(Save absolute file for future jobs)
EXIT.	
7/8/9	
Segmentation directives	
7/8/9	
Data	
6/7/8/9	

SCOPE 3.4 to transfer the data to disk, tape, etc. When used with the NOVA program under SCOPE 3.4, however, a FILE card is required prior to loading to specify the record type and block type. The REFRA routine will usually operate more efficiently when the information is on disk, so a transfer to disk is recommended whenever possible.

Input and output are equated with logical files TAPE5 and TAPE6, respectively.

Computation times will vary considerably depending on the structure, the complexity of the model, the response time required, and the number of iterations required to determine the critical range. In general, DEPROP, a three-dimensional code, will require more computer time than DEPROB, a two-dimensional code. Computer times for two sample problems are given in section 6.5.

Although program output is largely self-explanatory, the normal output is described in detail in tables 26-29. When possible, the corresponding program variable is given parenthetically.

If the INOUT option is specified in the NOVA input data set, the input data are included as part of the printed output thus recording the aircraft altitude and airspeed, the nuclear weapon yield and orientation at burst, and the data used to model the structural element.

Selection of additional debugging output (NDBUG=1,2) will yield additional information which can be useful to the analyst only when it is accompanied by careful examination of the program.

Certain errors in the input data, particularly those which cause calculated array sizes to exceed the allotted dimensions, and certain other errors detected by the program, are identified by error messages in the program output. The subroutines which originate these messages are given in table 30 along with an explanation of each message and the manner in which the error affects the program. It is the user's responsibility to check that the array sizes which he specifies in the input data do not exceed the limits given in tables 17, 18 and 19. For example, the number of masses (NMASS or N) in the NOVA and DEPROB cannot exceed

40 in this version of NOVA. If the user specifies 50 masses, no error message is given and the solution is erroneous. In most cases, the program, after identifying an error or a potential error, will automatically cycle to the next burst orientation or structural element so that the entire run is not necessarily wasted.

TABLE 26. NOVA HEADING OUTPUT

Aircraft altitude, ft (ALT)

Aircraft velocity, ft/sec (VEL)

Height of ground, ft (HG)

Weapon yield, KT(WKT)

Aircraft angle of attack, rad (ALFAA)

Horizontal tail incidence, rad (HTINC)

Blast model used and if ground reflection included (KB,KGRD)

Damage level code (KDAM)

Message indicating iteration restricted to constant altitude (omitted for KALT=0)

Probability of exceeding specified damage level (PDAM) (omitted if KDAM=2)

Structural element number (NEL)

Structural element identification (KTYPE)

Structural element location (ICOMP,IUL)

Internal pressurization, lb/in^2(PINT)

For each new trial or orientation, the following information is printed out:

Orientation number (NOR)

Direction cosines corresponding to above orientation (XOSRO(NOR), YOSRO(NOR), ZOSRO(NOR))

Range, ft (RTRIAL(1))

Number of the present trial in iteration for critical range (NTRIAL)(omitted if KDAM=2)

Message indicating whether aircraft is intercepted by the free-air or Mach shock.

TABLE 27. DEPROB STRUCTURAL RESPONSE OUTPUT

Heading Output

Integration interval, sec (DELTIM)

Mass of the structure, lb-sec^2/in (SMASSF)

Stop time, sec (TSTOP)

Message indicating whether the structure is circular or not.

Edge condition and coordinates of the two ends of the structure, relative to the center of gravity of the structure, in. (V1, W1, V2, W2)(omitted if KTYPE = 8 or 9)

Amplitude of initial imperfection (only for KTYPE=10)

Radius to the center of the ring, in (BIGR3) (omitted if KEYRG=2)

Table of material properties:

Number of flanges assigned to layer (FNFL)

Density of layer for the equivalent cross section, lb-sec^2/in^4 (RHO)

Geometrical description of each layer of cross section:

Layer number (L)

Thickness of layer at each station along beam, in (H)

Width of layer at each station along beam, in (H)

Width over which pressure is assumed to act, in (WT)

Area ratios associated with mechanical sublayer stress-strain model for each layer:

Layer number (L)

Area ratio for each sublayer (ARSL)

Position of each flange in cross-section for each station along beam:

Flange number

Position in cross-section, in (ZETA)

TABLE 27 (Continued)

Table of stress-strain information for compression:

Break point stresses for material in layer, lb/in^2 (STRSO)

Break point strains for material in layer, in/in (STRNA)

Stress-strain slope, lb/in^2 (SSS)

Table of stress-strain information for tension:

Same as the table for compression, with variables STRSOT, STRNAT, and SSST

Stiffness of each supporting longeron (omitted if NSEL=0), lb/in (E_{-})

Time-History Output

Integration step number (JTIM)

Time, sec (TIME)

End axial load (only for KTYPE=10), lb (PPP)

Edge strain information (clamped or clamped-sliding boundary condition only)

Edge strain at inner surface, in/in (EDGI)

Number of trials in iterative edge solution (NTI)

Table of response information:

y coordinate of mass point, in (VM)

z coordinate of mass point, in (WM)

Resultant internal force in bar preceding mass point, lb (BIGN)

Resultant internal moment, lb-in (BIGM)

Strain at inner surface, in/in (EPSILL)

Strain at outer surface, in/in (EPSILU)

Flag ("*") indicating if strain in any flange has exceeded the strain at the first break point in either tension or compression

TABLE 27. (Concluded)

Acceleration of mass point in the y direction, in/sec^2 (ACCNV)

Acceleration of mass point in the z direction, in/sec^2 (ACCNW)

External (lateral) pressure, lb/in^2 (PB)

Absolute value of net total displacement, in (DIS)

Summary Output (range iteration only)

Critical flange for damage criteria:

Bar in which flange is located (LSTMXI, LSTMXO, LSCMXI or LSCMXO)

Layer in which flange is located (LMAX)

Flange (KMAX)

Time at which maximum ratio of stress/strain to allowable stress/strain occurred, sec (TSTMXI, TSTMXO, TSCMXI or TSCMXO)

Critical strain, in/in (ETMXI, ETMXO, ECMXI or ECMXO)

Corresponding stress, lb/in^2, STMXI or STMXO (omitted for KDAM=1)

Maximum ratio of stress/strain to allowable stress/strain (CRIT(1))

Message indicating whether structural element yielded (that is, whether strain in any flange has exceeded the strain of the first break point in either tension or compression).

Net CP time for response, sec.

TABLE 28. DEPROP STRUCTURAL RESPONSE OUTPUT

Time-History Output

Time from shock arrival, sec (TIME)

External Pressure, lb/in^2 (PPP)

Normalized axial, tangential, and radial displacement modal coefficients for all modes, with the beta mode index varying most rapidly ((UU(I,J), VV(I,J), WW(I,J), J=1,MB), I=1,MG)

Table of stress-strain information (every third spatial point, inner and outer surfaces):

X coordinate, in (XG)
Beta position, in or deg (XB)
Depthwise position, in
Axial strain, dimensionless
Circumferential strain, dimensionless
Shearing strain, dimensionless
Axial stress, lb/in^2
Circumferential stress, lb/in^2
Shearing stress, lb/in^2
Flag ("*") indicating equivalent strain has exceeded yield strain (elastic runs only)
Counter indicating number of unloading and reyieldings (KY) (elastic-plastic runs only)

Displacement information (every third spatial point):

X-coordinate, in (XG)
Beta-position, in or deg (XB)
Axial displacement, in (UF)
Tangential displacement, in (VF)
Radial displacement, in (WF)

Summary Output (range iteration only)

Message indicating whether run was terminated normally or abnormally

Time at which computations stopped, sec (TIME)

Iterative trial number (NTRIAL)

Case number (NCASE)

Range, ft (RTRIAL(1))

Maximum ratio of stress (strain) to allowable stress (strain) (CRIT(1))

TABLE 28. (Concluded)

Time corresponding to maximum ratio, sec (TMAX)
Message indicating whether maximum ratio occurred in tension or compression.
Net CP time for response, sec
Number of integration points which yielded, if any. (Elastic-plastic response only)

TABLE 29. NOVA TERMINAL OUTPUT

For each element for each orientation for each trial, the following information is printed out:

Structural element number (NEL)

Orientation number (NOR)

Direction cosines corresponding to above orientation (XOSRO(NOR), YOSRO(NOR), ZOSRO(NOR))

Range, ft (RTRIAL(1))

Number of the present trial in iteration for critical range (NTRIAL) (omitted if KDAM=2)

Message indicating whether aircraft was intercepted by the free-air or Mach shock.

Components of vector from aircraft to burst point at shock arrival time, ft

Components of vector from aircraft to burst point at burst time, ft

Shock arrival time, sec

Shock overpressure, lb/in^2

When all structural elements have been considered, the following summary of results is printed out (omitted for KDAM=2):

Table containing the following information for each orientation and structural element considered:

Original orientation number (the direction cosines associated with this orientation number may have changed for a constant altitude iteration)

Structural element number

Components of critical range vector from aircraft to burst at shock arrival time

Components of critical range vector from aircraft to burst at burst time

Critical range, ft (RCRIT)

Shock overpressure, lb/in^2

TABLE 29. (Concluded)

Shock arrival time, sec.
Table indicating the critical element corresponding to each orientation considered:
Original orientation number
Structural element number

TABLE 30. ERROR MESSAGES

AIRCRAFT FLYING OUT OF BLAST REGION.

At the time at which the shock front and the aircraft center of gravity coincide for the given range and orientation, the aircraft is emerging from the shock region rather than being overtaken by the shock. Program sets critical range for given element and orientation equal to zero and continues to next case. (FPRES and WPRES)

ALTITUDE MUST BE GREATER THAN ZERO IN S/R REFRA.

The altitude of the burst must be above sea level. Program stops. (REFRA)

AMACH=XXX. GMACH=XXX.
PROGRAM IS TERMINATED IN S/R SETW DUE TO THE ABOVE VALUES.

The aircraft and gust Mach numbers cannot be -1.0 or 1.0. Program stops. (SETW)

AMBIENT CONDITIONS RETURNED BEHIND SHOCK IN FPRES, T=XXX.

Program expects nonambient conditions just behind shock but gets ambient conditions from BLAST. May need to increase time bias in BLAST. Program aborts this case and continues to next case. (FPRES)

A SMALLER RANGE IS NOT POSSIBLE FOR THIS ALTITUDE AND HOB. TRIALS COMPLETED=XXX. RANGE, CRIT XXX, XXX.

The minimum range possible has been found to be too large for an iteration constrained to constant altitude. Program aborts this case, and continues to next case. (RITC)

CAN NOT TOTALLY CORRECT FOR OVERSHOOT. XXX.

An iterative process to correct for overshoot associated with yielding has not converged in five trials. This probably means a numerical instability is creeping into the solution. Program continues until such errors occur 100 times. (See section 4.2.6.) (SIGMA)

TABLE 30. (Continued)

CRITERIA VS RANGE SLOPE REVERSAL IN RITER. NTRIAL=XXX. RANGE, CRIT, XXX,XXX.

The criterion, CRIT, has decreased with decreasing trial range or increased with increasing trial range, which violates the assumption of the range iteration program that the criterion increases monotonically as the trial range decreases. Program sets critical range for given element and orientation equal to zero and continues with next case. (RITER)

DATA OUT OF RANGE IN S/R BISH.
T = XXX. TIM (LLL) = XXX. TIM(LLU) = XXX.

This indicates an error in the program. Program stops. (BISH)

DC IS OUT OF RANGE IN S/R OPT2.

d_b, which is described on page 59, ref. 7, is not within the range of d_{max_K}'s on the data tape. Program flags the error and returns to the calling program. (OPT2)

DEPROB IS ABORTED AT T, SEC = XXX.

DEPROB returns control of program to NOVA due to error. This case is aborted. (DEPROB)

DEPROP IS ABORTED AT T, SEC = XXX.

DEPROP returns control of program to NOVA due to error. This case is aborted. (DEPROP)

DIMENSIONS ABOVE ARE NOT LARGE ENOUGH FOR REFRA TAPE.

The dimensions of the variables in REFRA need to be increased. Program stops. (REFRA)

ELC IS OUT OF RANGE IN S/R OPT2

ℓ_B, which is described on page 54, ref. 7, is not within the range of ℓ_{max_k}'s on the data tape. Program flags the error and returns to the calling program. (OPT2)

TABLE 30. (Continued)

END OF DATA REACHED ON TAPE XXX IN S/R ADVANC.

This indicates an error exists in the program or in the way the data tape was prepared. Program stops. (ADVANC)

END OF DATA REACHED ON TAPE XXX IN S/R READ.

This indicates an error exists in the program or in the way the data tape was prepared. Program stops. (READ)

END OF DATA REACHED ON TAPE XXX IN S/R SKIP.

This indicates an error exists in the program or in the way the data tape was prepared. Program stops. (SKIP)

EPP IS OUT OF RANGE

Numerical instability detected. A smaller Δt may be required. This case is aborted. (SIGMA)

FIRST ARGUMENT IS OUTSIDE TABLE, X = XXX. XT = XXX...XXX.

Tabulated data provided does not bracket first argument. Program stops. (INT2)

IMMEDIATE RELOADING, XXX.

Probable numerical instability creeping into solution. Program continues until such errors occur 100 times. (See section 4.2.6.) (SIGMA)

INSUFFICIENT DATA AVAILABLE IN FPRES XXX.

A REFRA tape with data at later times is required. Program aborts this case. (FPRES)

INSUFFICIENT DATA AVAILABLE IN WPRES XXX.

A REFRA tape with data at later times is required. Program aborts this case. (WPRES)

TABLE 30. (Continued)

INTERPOLATION ERROR IN INTP, X-VALUE XXX OUTSIDE TABLE. Y-VALUE RETURNED = XXX. X-TABLE = XXX.

Linear interpolation of pressure vs time has a time which is outside table. Indicates probable error in FPRES, WPRES or PINIT. Program continues. (INTP)

J OR JP IS OUT OF RANGE IN OPT2.

j, as calculated in equations 86 or 97, ref. 7, is too large. Program flags the error and returns to the calling program. (OPT2)

MORE THAN XXX LAYERS ARE REQUIRED IN DEPROB.

Available storage for variables dimensioned at NL has been exceeded. Case is aborted. (COMP1)

MORE THAN XXX SUBFLANGES REQUIRED IN LAYER XXX IN DEPROB.

Available storage for variables dimensioned at MAXSF has been exceeded due to an excessive number of stress-strain segments. Case is aborted. (COMP1)

MORE THAN XXX TOTAL FLANGES REQUIRED IN DEPROB XXX.

Available storage for variables dimensioned at NLK has been exceeded. Case is aborted. (COMP1)

NAMELIST NIOPT3

Possible error in IOPT3. Program may stop. (IOPT3)

NO ITERATIVE SOLUTION FOR THIS AZIMUTH.

A range iteration constrained to constant altitude cannot begin with the burst directly above or below aircraft. Program aborts this case. (RITC)

NUMBER OF CASES EXCEEDS STORAGE IN NOVA XXX.

The total combination of orientations and structural elements exceeds the maximum dimensions. Program prints summary and stops. (NOVA)

TABLE 30. (Continued)

NUMBER OF TRIALS COMPLETED = XXX. PROBLEM REQUIRED TOO MANY ITERATIONS OF RLAXB.

Too many iterations (20) were required to find static equilibrium. The final conditions are printed out. Program may need more trials and/or adjustment of the variable CON in RLAXB. This case is aborted. (DEFORM)

NUMBER OF TRIALS COMPLETED = XXX. SOLUTION DIVERGING IN S/R RLAXB, PROGRAM ABORTED IN S/R DEFORM.

Iterative process to find static equilibrium has failed. The final conditions are printed out. This case is aborted. (DEFORM)

PSI IS OUT OF RANGE IN S/R OPT2.

ψ_B, which is described on page 58, ref. 7, is not within the range of ψ_{T_k}'s on the data tape. Program flags the error and returns to the calling program. (OPT2)

RANGE ITERATION HAS NOT CONVERGED IN RITER. NTRIAL = XXX. RANGE, CRIT, XXX, XXX.

To avoid a possible iteration loop in searching for the critical range, the number of trials allowed is restricted. Iteration can be continued on a subsequent run by specifying appropriate directions cosines and range. Program aborts this case. (RITER)

SCALED GROUND RANGE OUTSIDE MACH SHOCK DATA TABLE IN XBLAST. IOPT, SH, SRMS, SRMT(1), SRMT(15). XXX....XXX

The scaled ground range SRMS is either too small or too large. A new range should be estimated for subsequent runs. Program aborts this case. (XBLAST)

SECOND ARGUMENT IS OUTSIDE TABLE, Y = XXX. YT = XXX...XXX.

Tabulated data provided does not bracket second argument. Program stops. (INT2)

SINGULARITY NEAR LEADING EDGE, TIME = XXX. X/C = XXX. CP = XXX.

Point on lifting surface is too near leading edge to obtain a meaningful pressure. Program continues. (POSTW1, POSTW4)

TABLE 30. (Continued)

SINGULAR MATRIX IN RLAXF. A = XXX.

The quasi-static edge solution cannot be found. Case is aborted except for rib elements. (RLAXF)

SINGULAR MATRIX IN S/R SOLVE.

The relaxation process has generated a singular matrix in determining static equilibrium. Program aborts this case. (SOLVE)

SOLUTION DIVERGING AT TIME, SEC = XXX.

Very large accelerations have been computed in CYCLE, indicating a numerical instability. A smaller Δt may be required. This case is aborted. (CYCLE)

SOLUTION DIVERGING IN DEPROP.

Very large accelerations have been computed in DERV2, indicating a numerical instability. A smaller Δt may be required. This case is aborted. (DERV2)

SOLUTION DIVERGING IN RELAXP.

The iterative process to find static equilibrium has failed. Program aborts this case. (RELAXP)

SOLUTION DIVERGING IN RLAXF. TIME, SEC = XXX.

The quasi-static edge solution cannot be found. A smaller Δt may be required. For a structure which can buckle, this may also indicate dynamic buckling. Case is aborted except for rib elements. (FB)

SOLUTION IS UNSTABLE.

Numerical instability has been detected in elastic-plastic solution. A smaller Δt is required. This case is aborted. (SIGMA)

STATIC SOLUTION ABORTED, NTR = XXX.

Static equilibrium cannot be found. Program continues. (DEFORM)

TABLE 30. (Continued)

STORAGE REQUIRED FOR WING PRESSURES EXCEEDS AVAILABLE STORAGE.

Allowable storage for variables dimensioned at NTP1+1 has been exceeded in the calculation of pressure on a lifting surface. Program aborts this case. (WPRES)

TAPE XXX IS IN POSITION JUST PRIOR TO TRANSITION IN S/R ADVANC. NT = XXX.

This indicates an error exists in the program or in the way the data tape was prepared. Program stops. (ADVANC)

TAPE XXX IS IN POSITION JUST PRIOR TO TRANSITION IN S/R SKIP.

This indicates an error exists in the program or in the way the data tape was prepared. Program stops. (SKIP)

TAUB IS OUT OF RANGE IN S/R OPT2

τ_B, which is described on page 54, ref. 7, is not within the range of τ_{T_K}'s on the data tape. Program flags the error and returns to calling program. (OPT2)

THE NUMBER OF MASS POINTS MUST BE EVEN IN DEPROB. N = XXX.

For KTYPE = 8 or 9, an even number of masses must be used. This case is aborted. (READ1)

THE VALUE OF LBAR IS INVALID. LBAR = XXX.

An incorrect value of LBAR has been specified. This case is aborted. (LEGEND)

THE X COORDINATE IS GREATER THAN THAT OF THE TRAILING EDGE.

The chordwise position at which pressure is desired is aft of the trailing edge. Program stops. (PREW)

THE X COORDINATE IS LESS THAN THAT OF THE LEADING EDGE.

The chordwise position at which pressure is desired is in front of the leading edge. Program stops. (PREW)

TABLE 30. (Continued)

THE Y COORDINATE IS LARGER THAN THE EFFECTIVE SPAN.

The spanwise coordinate of the point at which pressure is desired is greater than the span as defined by the points which specify the leading and trailing edges. Program stops. (PREW)

THE Y COORDINATE IS LESS THAN ZERO.

The spanwise coordinate of the point at which pressure is desired is smaller than the first point defining the leading edge. Program stops. (PREW)

TIME REQUESTED EXCEEDS LAST REFRA TIME XXX, XXX.

A REFRA tape with data at later times is required. Program aborts this case. (BLAST)

TOO FEW TIMES ON DATA TAPE XXX IN S/R CPT1.

Data is needed for a time for which there is no data on the tape. Three times are printed out in seconds: the time requested, the first time on the tape and the last time on the tape. Program stops. (OPT1)

TOO FEW TIMES ON REFRA TAPE FOR MACH SHOCK IN S/R OPT2.

The searching process described on page 59, ref. 7, failed to find a time on the data tape. Program flags the error and returns to the calling program. (OPT2)

TOO FEW TIMES ON REFRA TAPE FOR REF SHOCK IN S/R OPT2.

The data tape does not extend far enough in time for Option 2. Program flags the error and returns to the calling program. (OPT2)

TOO LITTLE STORAGE FOR FN ARRAY, XXX.

The dimensions for FN, or the variables representing the dimensions, MAXSF, MAXLK and N, are not sufficiently large for the problem. This case is aborted. (COMP1)

TOO MANY ITERATIONS IN WFPKOD. XXX.

Convergence has not been obtained in function WFPKOD. Program continues. (WFPKOD)

TABLE 30. (Continued)

TOO MANY TRIALS IN FB XXX.
TIME, SEC = XXX.

The quasi-static edge solution cannot be found. A smaller Δt may be required. For a structure which can buckle, this may also indicate dynamic buckling. Case is aborted except for rib elements. (FB)

TOO MANY TRIALS IN STATIC SOLUTION. MTR = XXX.

To avoid looping indefinitely in attempting a solution representing static equilibrium, an upper limit of 10 is placed on the number of trials. Program may need more trials and adjustment of the variable CON in RELAXP. (DEPROP)

VALUE OF NU WON'T CONVERGE XXX XXX, TIME, SEC = XXX.

Numerical instability detected. This case is aborted. (SIGMA)

WARNING - HONEYCOMB PANEL, PROGRAM ASSUMES FACE SHEETS ARE LAYERS 1 AND 3, BUT PANEL HAS XX LAYERS.

The code KTYPE is equal to 3 or 4, indicating a honeycomb panel, which the program assumes to have three layers, two face sheets and a core. The panel does not have three layers, however. Program continues (CSETUP)

WARNING - ONE OF THESE FOUR PARAMETERS HAS EXCEEDED THE LIMITS OF ITS CURVE FIT IN S/R PREW.*** ETA = XXX, SWPM = XXX, TRATIO = XXX, ASPRM = XXX.

A quadratic curve fit of aerodynamic data may be invalid. The four parameters and their domains are:

$0.0 \leq$ ETA ≤ 0.924	Percent of semispan
$0.0 \leq$ SWPM ≤ 1.0472	Modified Sweep Parameter, Λ_β, (see table 2)
$0.0 \leq$ TRATO ≤ 1.0	Taper ratio, λ.
$1.5 \leq$ ASPRM ≤ 8.0	Modified aspect ratio, β_A, (see table 2)

Program applies quadratic fit and continues. (PREW)

TABLE 30. (Continued)

WARNING - ORIENTATION OF BLAST IS INCORRECT FOR SYMMETRIC RESPONSE XXX.

A frame element modeled so as only half of element is analyzed must receive blast loading so as to preserve symmetry. Program continues. (PINIT)

X - VALUE XXX, OUTSIDE TABLE. Y-VALUE RETURNED = XXX. X-TABLE = XXX.

Tabulated data do not bracket X-value given. Nearest value is returned. Program continues. (INT1)

X-VALUE XXX OUTSIDE TABLE. Y-VALUE RETURNED = XXX. X-TABLE = XXX...XXX. Y-TABLE = XXX...XXX. ADDRESS OF X = XXX. ADDRESS OF NX = XXX. ADDRESS OF XT = XXX. ADDRESS OF YT = XXX. ADDRESS OF R = XXX.

Tabulated data provided do not bracket X-Value given. Tables and addresses are printed out to help user to identify problem. Program stops. (INTSLO)

ZETA NOT IN RANGE

Zeta (as found from equation 58, page 45, ref. 7) is not between 0 and 1. ZETA is set equal to 1 and the program continues. (OPT1)

ZETA1 NOT IN RANGE

Zeta (as found from equation 58, page 45, ref. 7) is not between 0 and 1. ZETA1 is set equal to 1 and the program continues. (OPT1)

**** WARNING **** - ELASTIC CURVES IN TENSION AND COMPRESSION DIFFER SIGNIFICANTLY IN LAYER XXX.

The stress-strain curves in tension and compression must have the same modulus of elasticity. Here they differ by more than 10%. Program continues. (COMP1)

**** WARNING **** - STATIC PRELOAD CANNOT BE FOUND FOR THESE CONDITIONS. KEYB1 = XXX. KEYB2 = XXX.

Only selected combinations of boundary conditions can be treated statically. Program continues without preblast load. (DEFORM)

TABLE 30. (Concluded)

**** WARNING **** YIELD STRAIN HAS BEEN EXCEEDED DURING STATIC LOADING. ONLY ELASTIC SOLUTIONS ARE ALLOWED. Static equilibrium has been reached, but yield strain has been exceeded. Solution is constrained to be elastic, so inconsistencies may arise during dynamic response. The preload is probably too large. Program continues. (DEFORM)

6.5 EXAMPLE PROBLEMS

Presented in this section are the results of three example problems intended to demonstrate the use of the DEPROB and DEPROP options of NOVA and the REFRA ground-reflected blast model. These examples are also intended to serve as check cases for running the code. The structural elements consist of a curved metal panel and a stringer. Data for the components are taken from reference 51. Certain data have been modified to better demonstrate the code. Also, relatively few modes are used in the DEPROP model to minimize the computer time needed to exercise the examples.

The first element considered is a titanium alloy panel situated between frames on an aft fuselage section; it is assumed to be clamped on all edges. A threshold of permanent damage criteria is selected, and the aircraft altitude and burst orientation specified so that the aircraft is intercepted by a Mach shock. This and the other two examples involve a scaled burst height of 525 feet. In this case, the analytical curve-fit ground reflection model is used (KB=2).

Figure 81 presents the input data used: first a listing of the data cards, then the interpretation by the program. It shows that DEPROP computes a time increment of 3.36 μsec. As will be seen, less than 1 millisecond of response is required to capture peak response. Therefore, only 298 integration steps are required.

From the program output, most of which is presented in figure 82, an initial range estimate of 2600 feet turns out to be a very propitious choice; the critical response compared to the appropriate allowable is 0.968, very near the desired ratio of 1.0. In this case the critical stress occurred at 0.739 millisecond. The output shows that the panel deflected outward 0.00032 inch (at the center) due to the net preblast load on it. At 0.538 millisecond into the response (corresponding to the printout included in fig. 82) the panel has deflected 0.270 inch inward. From the radial displacement coefficients (WRS) at that time, it can be seen that the dominant modes involve the first gamma mode; if more accuracy were required one would probably begin by adding modes

1,4; 1,5; etc. Based on the response, the program predicts a critical range of 2535 feet and terminates after only the one iteration. The computer time required is only 57 seconds.

After computing a new range vector, shock overpressure, and shock arrival time, the results are summarized as final output. If more than one structural element had been considered, or if additional orientations had been considered, the summary would select the element most susceptible to that damage level for each orientation.

The second example problem involves an aluminum skin-stringer combination on the horizontal tail. Again, clamped edges are assumed, and due to symmetry only one half of the element is modeled. A threshold of permanent damage criteria is selected. In this case, the REFRA ground reflection blast model is used to provide the dynamic loading (KB=1).

The actual input data are presented in figure 83. A listing of the data cards is followed by the interpretation by the program, including some additional parameters computed by the program. The appropriate integration time increment of 4.46 μsec is calculated.

This problem requires two iterations before selecting a final estimated range. Selected portions of the output are contained in figure 84. For example, the response output is shown at t=0, t=0.214 msec, (the time approximately corresponding to peak response), and at t=0.3 msec corresponding to the final output. The printout at t=0.214 msec indicates a center deflection of about 0.050 inch and the maximum strain (-0.005299), which is slightly less than the yield strain, occurs in the segment nearest the wall. The element is not allowed to yield, however, because of the threshold damage criteria selected.

The output indicating range and "CRIT" (ratio of maximum response to critical value) are presented for each of the two trial ranges. In general, if the logarithm of "CRIT" is plotted versus range, the points will quickly indicate the critical range where, by definition, CRIT=1. The program estimates a final range of 2719 feet and summarizes the results. The entire run consumed 95 CP seconds of computer time.

The third example problem is identical to the second, except the analytical blast model (KB=2) is used for comparison. In both cases the aircraft is intercepted by the Mach shock. Here the final estimated range is 2924.1 feet with a corresponding shock overpressure of 10.594 psi (figure 85). When compared with the REFRA results, this indicates the analytical model predicts a critical range 7.6 percent larger than REFRA due to a predicted shock overpressure which is 24.7 percent higher.

```
     NOVA-2 SAMPLE PROBLEM - CURVED PANEL ON FUSELAGE
           1            0
5000.        935.         10.          4950.
0.1          -.1          0.0          0.0
          22           22
0.0          -0.89638     -0.44329
2600.0
                                                            (BLANK CARD)
           2            1
           0            1
0.50
           0
           2            2
-342.3       0.0
-513.5       269.
-551.3       0.0
-576.4       269.
           0
           6
1150.        -594.
0.0          0.0
1025.        28.5
628.         60.
350.         49.
50.          52.5
-304.        55.
-450.        41.
           2            1
           5
0.785
0.0
0.0
           3            3            7            7            1
           1            1            1
           0
           1
8.3          48.          81.
0.055        0.000415
      0.16E8       0.16E80.3    0.3                0.62E7
      0.12E6      0.126E6
0.           0.           0.           0.           0.           0.
0.           0.           0.
0.0          0.001        20.
                                                            (BLANK CARD)
```

Figure 81. Example Input Data for Curved Panel on Fuselage

NOVA-2 SAMPLE PROBLEM - CURVED PANEL ON FUSELAGE

AIRCRAFT ALTITUDE (ALT), FT	.5000000E+04
AIRCRAFT VELOCITY (VEL), FT/SEC	.9350000E+03
WEAPON YIELD (WKT), KT	.1000000E+02
HEIGHT OF GROUND (HG), FT	.4950000E+04
AIRCRAFT ANGLE OF ATTACK (ALFAA), RAD	.1000000E+00
HORIZONTAL TAIL INCIDENCE (HTINC), RAD	-.1000000E+00
FUSELAGE BEND ANGLE (BAF), RAD	0.
FUSELAGE BEND POSITION (XBF), IN	0.

ORIENTATION	XOSRO	YOSRO	ZOSRO	REST
22	0.000000	-.896380	-.443290	.260000E+04

Figure 81. (Continued)

```
BLAST MODEL USED - ANALYTICAL CURVE FIT
  GROUND REFLECTION INCLUDED
ITERATION RUN
  NO DAMAGE LEVEL, PROBABILITY OF EXCEEDING  .500
  ITERATION RESTRICTED TO CONSTANT ALTITUDE

NUMBER OF POINTS TO DEFINE LEADING EDGE OF HORIZONTAL TAIL    2
X COORDINATE,IN
  -.3423000E+03  -.5135000E+03
Y COORDINATE,IN
  0.              .2690000E+03

NUMBER OF POINTS TO DEFINE TRAILING EDGE OF HORIZONTAL TAIL    2
X COORDINATE,IN
  -.5513000E+03  -.5764000E+03
Y COORDINATE,IN
  0.              .2690000E+03

X COORDINATE OF NOSE OF FUSELAGE, IN     .1150000E+04
X COORDINATE OF TAIL OF FUSELAGE, IN    -.5940000E+03
Y COORDINATE OF FUSELAGE AXIS, IN        0.
Z COORDINATE OF FUSELAGE AXIS, IN        0.

FUSELAGE    STATION, IN      RADIUS, IN
           .102500E+04     .285000E+02
           .628000E+03     .600000E+02
           .350000E+03     .490000E+02
           .500000E+02     .525000E+02
          -.304000E+03     .550000E+02
          -.450000E+03     .410000E+02
SECTION ANALYZED =    5
THETAP =    .78500E+00

SINGLE-LAYER METAL PANEL ON
FUSELAGE
DRDX =  0.

INTERNAL PRESSURIZATION =  0.          PSI
```

Figure 81. (Continued)

```
INPUT DATA FOR GERPROP

MG      =  3
NB      =  3
MBAR    =  7
NBAR    =  7
LBAR    =  1

NPLT    =  1
NBND    =  1
NDERV   =  1

NNOUT  =   0

NI      =  1

XLP, IN           =    .83000000E+01
THETAO, DEG       =    .48000000E+02
A, IN             =    .81000000E+02

LAYER   1
   HM, IN                     =    .55000000E-01
   RHOM, LB-SEC**2/IN**4      =    .41500000E-03
   FX, PSI                    =    .16000000E+03
   FT, PSI                    =    .16000000E+08
   XXNU                       =    .30000000E+00
   THNU                       =    .30000000E+00
   GXT, PSI                   =    .62000000E+07
   SAT, PSI                   =    .12000000E+06
   SAC, PSI                   =    .12600000E+06

FG =
 0.              0.              0.              0.              0.
 0.              0.              0.              0.

DELTIM, SEC  =   0.
TSTOP, SEC   =    .10000000E-02
PRINT        =    .20000000E+02
```

Figure 81. (Continued)

```
                    D E P R O P
PANEL ANALYZED
  CURVED
  METAL, SINGLE LAYER
  CLAMPED - CLAMPED, GAMMA DIRECTION
  CLAMPED - CLAMPED, BETA DIRECTION

RESPONSE OPTION - ELASTIC

STRUCTURAL MODEL
  NUMBER OF GAMMA MODES (MG)                        =    3
  NUMBER OF BETA MODES   (MH)                       =    3

  NUMBER OF GAMMA INTEGRATION POINTS (MBAR)         =    7
  NUMBER OF BETA INTEGRATION POINTS  (NBAR)         =    7
  NUMBER OF Z INTEGRATION POINTS     (LBAR)         =    1

  LENGTH OF PANEL, IN (XLP)       =    .83000000E+01
  SUBTENDED ANGLE, DEG (THETA0) =    .48000000E+02
  RADIUS, IN (A)                  =    .81000000E+02

COORDINATE SURFACE POSITION (HBAR), IN    .27500000E-01

LAYER NUMBER                                          1
  CUMULATIVE THICKNESS, IN                       .550000E-01
  MASS DENSITY, LB-SEC**2/IN**4                  .415000E-03
  MODULUS OF ELASTICITY - X, PSI                 .160000E+08
  MODULUS OF ELASTICITY - THETA, PSI             .160000E+08
  POISSON#S RATIO - X                            .300000E+00
  POISSON#S RATIO - THETA                        .300000E+00
  SHEAR MODULUS, PSI                             .620000E+07
  TENSILE YIELD STRESS, PSI                      .120000E+06
  COMPRESSIVE YIELD STRESS, PSI                  .126000E+06

INITIAL IMPERFECTIONS, IN
 0.            0.            0.            0.            0.
 0.            0.            0.            0.

TIME INFORMATION
  INTEGRATION STEP SIZE, SEC (DELTIM)   =    .33603274E-05
  STOP TIME, SEC (TSTOP)                =    .10000000E-02
  PRINT FREQUENCY (PRINT)               =    .20000000E+02
```

Figure 81. (Concluded)

```
AIRCRAFT ALTITUDE (ALT), FT                       .5000000E+04
AIRCRAFT VELOCITY (VEL), FT/SEC                   .9350000E+03
WEAPON YIELD (WKT), KT                            .1000000E+02
HEIGHT OF GROUND (HG), FT                         .4950000E+04
AIRCRAFT ANGLE OF ATTACK (ALFAA), RAD             .1000000E+00
HORIZONTAL TAIL INCIDENCE (HTINC), RAD           -.1000000E+00

BLAST MODEL USED - ANALYTICAL CURVE FIT
  GROUND REFLECTION INCLUDED

ITERATION RUN
  ITERATION RESTRICTED TO CONSTANT ALTITUDE
  NO DAMAGE LEVEL, PROBABILITY OF EXCEEDING  .500

STRUCTURAL ELEMENT  1

SINGLE-LAYER METAL PANEL ON
FUSELAGE

INTERNAL PRESSURIZATION =  0.          PSI

ORIENTATION 22          XOSRO =  0.                  YOSRO =  -.89638E+00

RANGE =   .26000E+04 FEET                                  ZOSRO =  -.44329E+00

TRIAL NUMBER  1

POINT INTERCEPTED BY MACH SHOCK
```

Figure 82. Example Output for Curved Panel on Fuselage

T = 0. SEC
PRESSURE AT CENTER,PSI = .3766717E+02

GAMMA	BETA	UPS	VRS	WRS
1	1	.9344221E-08	.9966182E-08	-.1834858E-05
1	2	.2494885E-08	.1809196E-07	-.8793694E-06
1	3	.1054738E-08	.2258282E-07	-.6787299E-06
2	1	.4470708E-09	-.4637724E-10	-.1422439E-06
2	2	.1790106E-09	-.1118695E-09	-.6763467E-07
2	3	.5677181E-10	-.2150260E-09	-.5385510E-07
3	1	.1530951E-09	.2213994E-11	-.2355982E-07
3	2	.1260588E-10	-.1807061E-10	-.1090230E-07
3	3	.9055002E-11	-.3015198E-10	-.8951193E-08

X (IN)	BETA (DEG)	Z (IN)	EXX (IN/IN)	ETT (IN/IN)	EXT (IN/IN)	SIGMA XX (PSI)
0.00	0.00	-.0275	.714668E-20	.943106E-22	0.	.126153E-12
0.00	0.00	.0275	-.714668E-20	-.943106E-22	0.	-.126153E-12
0.00	12.00	-.0275	.610690E-05	-.182429E-09	-.366215E-06	.107373E+03
0.00	12.00	.0275	-.503223E-05	.182429E-09	-.365464E-06	-.884779E+02
0.00	24.00	-.0275	.665771E-05	-.187409E-09	.131725E-19	.117058E+03
0.00	24.00	.0275	-.555370E-05	.187409E-09	.131814E-19	-.976465E+02
2.08	0.00	-.0275	-.140799E-20	.925798E-06	.819989E-07	.488333E+01
2.08	0.00	.0275	.140799E-20	.273891E-06	.819989E-07	.144470E+01
2.08	12.00	-.0275	-.113856E-05	.213421E-05	-.693442E-06	-.876126E+01
2.08	12.00	.0275	.104899E-05	.216112E-05	.962279E-07	.298431E+02
2.08	24.00	-.0275	-.123231E-05	.223678E-05	.878098E-14	-.986859E+01
2.08	24.00	.0275	.116331E-05	.241137E-05	-.871527E-14	.331731E+02
4.15	0.00	-.0275	-.193998E-20	.136623E-05	.819671E-21	.720650E+01
4.15	0.00	.0275	.193998E-20	.354108E-06	.819671E-21	.186782E+01
4.15	12.00	-.0275	-.195326E-05	.334706E-05	-.339920E-15	-.166881E+02
4.15	12.00	.0275	.107606E-05	.338947E-05	.336518E-15	.367983E+02
4.15	24.00	-.0275	-.211534E-05	.349786E-05	.764806E-23	-.187425E+02
4.15	24.00	.0275	.117067E-05	.376744E-05	-.755992E-23	.404555E+02

X(IN)	BETA(DEG)	U(IN)	V(IN)	W(IN)
0.	0.	0.	0.	-.6914724E-34
0.	.1200000E+02	0.	0.	-.5383010E-19
0.	.2400000E+02	0.	0.	-.5956590E-19
.2075000E+01	0.	0.	0.	-.2434448E-18
.2075000E+01	.1200000E+02	.6087097E-06	-.7148204E-06	-.1894150E-03
.2075000E+01	.2400000E+02	.6281169E-06	.2538719E-19	-.2059116E-03
.4150000E+01	0.	0.	0.	-.3789626E-18
.4150000E+01	.1200000E+02	.6246094E-20	-.1032987E-05	-.2949046E-03
.4150000E+01	.2400000E+02	.6726520E-20	.3662876E-19	-.3197268E-03

Figure 82. (Continued)

SIGMA TT (PSI)	SIGMA XT (PSI)
.393550E-13	0.
-.393550E-13	0.
.322090E+02	-.227053E+01
-.265404E+02	-.227207E+01
.351143E+02	.816692E-13
-.292909E+02	.817247E-13
.162778E+02	.508393E+00
.481566E+01	.508393E+00
.315189E+02	-.429934E+01
.435308E+02	.596613E+00
.328279E+02	.544421E-07
.485339E+02	-.540347E-07
.240217E+02	.508196E-14
.622608E+01	.508196E-14
.485465E+02	-.210751E-08
.652711E+02	.208641E-08
.503430E+02	.474180E-16
.724157E+02	-.468715E-16

(t = 0.0)

SIGMA TT (PSI)	SIGMA XT (PSI)
-.322937E-10	0.
.322937E-10	0.
-.243261E+05	-.149046E+04
.269984E+05	-.149147E+04
-.280648E+05	.344136E-11
.286870E+05	.344370E-11
-.111780E+05	-.151963E+04
-.295382E+04	-.151963E+04
-.162730E+05	.128614E+03
-.240257E+05	-.251624E+04
-.157284E+05	.747329E-04
-.263688E+05	.142678E-03
-.233429E+05	-.167231E-10
-.950192E+04	-.167231E-10
-.293677E+05	-.589354E-05
-.481522E+05	-.204930E-04
-.320776E+05	.218411E-12
-.535882E+05	.487265E-12

(t = 0.5376524E-3)

Figure 82. (Continued)

T = .5376524E-03 SEC
PRESSURE AT CENTER,PSI = .3525466E+02

GAMMA	BETA	URS	VRS	WRS
1	1	-.3076980E-04	-.1180367E-04	.1573525E-02
1	2	-.6394228E-05	-.1539821E-04	.6960784E-03
1	3	-.1557685E-05	-.1919889E-04	.4785390E-03
2	1	.9628724E-05	.7817781E-06	.1086408E-03
2	2	.2354273E-05	.2589332E-05	.3664507E-04
2	3	-.1546656E-06	.5914110E-05	.2676474E-04
3	1	.4971224E-05	-.5699425E-07	.3211074E-04
3	2	.8014893E-06	-.1861736E-06	.1977303E-04
3	3	.4874290E-07	-.8861715E-07	.1867896E-04

X (IN)	BETA (DEG)	Z (IN)	EXX (IN/IN)	ETT (IN/IN)	EXT (IN/IN)	SIGMA XX (PSI)
0.00	0.00	-.0275	-.595218E-17	-.510486E-19	0.	-.104923E-09
0.00	0.00	.0275	.595218E-17	.510486E-19	0.	.104923E-09
0.00	12.00	-.0275	-.461153E-02	-.859803E-07	-.240396E-03	-.810823E+05
0.00	12.00	.0275	.511815E-02	.859803E-07	-.240560E-03	.899900E+05
0.00	24.00	-.0275	-.532056E-02	-.200216E-07	.555058E-18	-.935484E+05
0.00	24.00	.0275	.543851E-02	.200216E-07	.555435E-18	.956222E+05
2.08	0.00	-.0275	.610907E-18	-.635748E-03	-.245101E-03	-.335339E+04
2.08	0.00	.0275	-.610907E-18	-.167998E-03	-.245101E-03	-.886145E+03
2.08	12.00	-.0275	.273325E-02	-.174550E-02	.207442E-04	.388501E+05
2.08	12.00	.0275	.136579E-02	-.177620E-02	-.405845E-03	.146450E+05
2.08	24.00	-.0275	.333509E-02	-.189508E-02	.120537E-10	.486429E+05
2.08	24.00	.0275	.169710E-02	-.200885E-02	.230126E-10	.192429E+05
4.15	0.00	-.0275	.240741E-17	-.132763E-02	-.269727E-17	-.700286E+04
4.15	0.00	.0275	-.240741E-17	-.540422E-03	-.269727E-17	-.285058E+04
4.15	12.00	-.0275	.355464E-02	-.273668E-02	-.950571E-12	.480638E+05
4.15	12.00	.0275	.152435E-03	-.278439E-02	-.330532E-11	-.120067E+05
4.15	24.00	-.0275	.341265E-02	-.284821E-02	.352276E-19	.449791E+05
4.15	24.00	.0275	-.351879E-04	-.303727E-02	.785911E-19	-.166395E+05

X(IN)	BETA(DEG)	U(IN)	V(IN)	W(IN)
0.	0.	0.	0.	.3746459E-31
0.	.1200000E+02	0.	0.	.3737432E-16
0.	.2400000E+02	0.	0.	.4571946E-16
.2075000E+01	0.	0.	0.	.1843461E-15
.2075000E+01	.1200000E+02	-.2367220E-02	.1277974E-03	.1565017E+00
.2075000E+01	.2400000E+02	-.2442290E-02	-.1562683E-16	.1691354E+00
.4150000E+01	0.	0.	0.	.3113444E-15
.4150000E+01	.1200000E+02	-.2637183E-16	.1017293E-02	.2553241E+00
.4150000E+01	.2400000E+02	-.2402899E-16	-.4532047E-16	.2702428E+00

Figure 82. (Continued)

```
NORMAL DEPROP STOP CONDITION AT T, SEC =     .100474E-02

RESULTS OF TRIAL  1 OF CASE  1
  RANGE, FT         =    .26000000E+04
  CRIT(1)           =    .96877226E+00
  TIME, SEC         =    .73927204E-03
  TENSION

NET CP TIME FOR RESPONSE, SEC =       9.098




STRUCTURAL ELEMENT  1

ORIENTATION 22          XOSRO =  0.                          YOSRO =  -.89638E+00

RANGE =   .26000E+04 FEET                                          ZOSRO =  -.44329E+00

TRIAL NUMBER  1

POINT INTERCEPTED BY MACH SHOCK

VECTOR FROM AIRCRAFT T  BURST POINT AT SHOCK ARRIVAL
X =   0.             FEET       Y =    .233059E+04 FEET       Z =    .115255E+04 FEET

VECTOR FROM AIRCRAFT TO BURST POINT AT BURST TIME
X =    .126031E+04 FEET       Y =    .233059E+04 FEET       Z =    .115255E+04 FEET

SHOCK ARRIVAL TIME =    .134793E+01 SEC

SHOCK OVERPRESSURE =    .135771E+02 PSI
```

Figure 82 . (Continued)

```
END OF ITERATION
ESTIMATED RANGE, FT =      .253484E+04


STRUCTURAL ELEMENT  1

ORIENTATION 22          XOSRO =  0.                        YOSRO =  -.89065E+00

RANGE =   .25348E+04 FEET                                      ZOSRO =  -.45468E+00

POINT INTERCEPTED BY MACH SHOCK

VECTOR FROM AIRCRAFT TO BURST POINT AT SHOCK ARRIVAL
X =  0.          FEET       Y =   .225766E+04 FEET       Z =   .115255E+04 FEET

VECTOR FROM AIRCRAFT TO BURST POINT AT BURST TIME
X =   .121442E+04 FEET       Y =   .225766E+04 FEET       Z =   .115255E+04 FEET

SHOCK ARRIVAL TIME =   .129885E+01 SEC

SHOCK OVERPRESSURE =   .142251E+02 PSI
```

Figure 82 . (Continued)

SUMMARY OF NOVA RESULTS
NOVA-2 SAMPLE PROBLEM - CURVED PANEL ON FUSELAGE

ORIGINAL ORIENTATION NUMBER	STRUCTURAL ELEMENT NUMBER	VECTOR FROM AIRCRAFT TO BURST POINT AT SHOCK ARRIVAL X (FT)	Y (FT)	Z (FT)	VECTOR FROM AIRCRAFT TO BURST POINT AT BURST TIME X (FT)	Y (FT)	Z (FT)
22	1	0.0	2257.7	1152.6	1214.4	2257.7	1152.6

TABLE OF THE CRITICAL ELEMENT FOR EACH ORIENTATION

ORIGINAL ORIENTATION NUMBER	CRITICAL ELEMENT NUMBER	RANGE (FT)	SHOCK OVERPRESSURE (PSI)	SHOCK ARRIVAL TIME (SEC)
22	1	2534.8	14.225	1.299

Figure 82. (Concluded)

```
NOVA-2  SAMPLE PROBLEM - STRINGER ON HORIZONTAL TAIL
              1              0
5000.          935.           10.           4950.
.1             -.1            0.            0.
             22             22
0.             -.69636        -.44329
2600.
                                                                                  (BLANK CARD)
              1              1
              0              1
.5
              0              0
              2              2
-342.3         0.
-513.5         269.
-551.3         0.
-576.4         269.
              0              0
              6
1150.          -594.
      0.       0.
1025.          28.5
628.           60.
350.           49.
50.            52.5
-304.          55.
-450.          41.
              3              6              1
-520.          210.           130.
0.
              2              2              5              1              1              0
              7              2              6
0.             0.
1.             0.
2.             0.
3.             0.
4.             0.
5.             0.
6.             0.
7.             0.
7.5            0.
              0
              0              0
.000259        .000259
4.
.006
4.
              3
.0055          58000.
.0081          73000.
.1             75000.
.97
.072
              3
.0055           58000.
.0081          73000.
.1             75000.
0.             .003           20.
                                                                                  (BLANK CARD)
```

Figure 83. Example Input Data for Stringer on Horizontal Tail

```
NOVA-2 SAMPLE PROBLEM - STRINGER ON HORIZONTAL TAIL

AIRCRAFT ALTITUDE (ALT), FT                         .5000000E+04
AIRCRAFT VELOCITY (VEL), FT/SEC                     .9350000E+03
WEAPON YIELD (WKT), KT                              .1000000E+02
HEIGHT OF GROUND (HG), FT                           .4950000E+04
AIRCRAFT ANGLE OF ATTACK (ALFAA), RAD               .1000000E+00
HORIZONTAL TAIL INCIDENCE (HTINC), RAD             -.1000000E+00

FUSELAGE BEND ANGLE (BAF), RAD                     0.
FUSELAGE BEND POSITION (XBF), N                    0.


ORIENTATION     XOSRO         YOSRO         ZOSRO          REST

    22        0.000000     -.856380      -.443290      .260000E+04
```

Figure 83. (Continued)

```
BLAST MODEL USED - ANALYTICAL CURVE FIT
  GROUND REFLECTION INCLUDED
ITERATION RUN
  NO DAMAGE LEVEL, PROBABILITY OF EXCEEDING  .500
  ITERATION RESTRICTED TO CONSTANT ALTITUDE

NUMBER OF POINTS TO DEFINE LEADING EDGE OF HORIZONTAL TAIL    2
X COORDINATE,IN
  -.3423000E+03  -.5135000E+03
Y COORDINATE,IN
  0.               .2690000E+03

NUMBER OF POINTS TO DEFINE TRAILING EDGE OF HORIZONTAL TAIL    2
X COORDINATE,IN
  -.5513000E+03  -.5764000E+03
Y COORDINATE,IN
  0.               .2690000E+03

X COORDINATE OF NOSE OF FUSELAGE, IN     .1150000E+04
X COORDINATE OF TAIL OF FUSELAGE, IN    -.5940000E+03
Y COORDINATE OF FUSELAGE AXIS, IN         0.
Z COORDINATE OF FUSELAGE AXIS, IN         0.

FUSELAGE   STATION, IN      RADIUS, IN
          .102500E+04    .285000E+02
          .628000E+03    .600000E+02
          .350000E+03    .490000E+02
          .500000E+02    .525000E+02
         -.304000E+03    .550000E+02
         -.450000E+03    .410000E+02

COORDINATE AT WHICH PRESSURE IS DESIRED
XP =   -.520000E+03 INCHES        YP =    .210000E+03 INCHES        ZP =    .130000E+03 INCHES

METAL: STRINGER OR LONGERON ON
HORIZONTAL TAIL
UPPER SURFACE

INTERNAL PRESSURIZATION =  0.          PSI
```

Figure 83. (Continued)

```
INPUT DATA FOR DEPROB

KEYRG   =  2
KEYR1   =  2
KEYR2   =  5
KUNF    =  1
KIS     =  1
KSUP    =  0

N       =   7
NL      =   2
NX      =   6

V1, IN        =   0.
W1, IN        =   0.

   I         VM(I), IN        WM(I), IN
   1        .100000E+01      0.
   2        .200000E+01      0.
   3        .300000E+01      0.
   4        .400000E+01      0.
   5        .500000E+01      0.
   6        .600000E+01      0.
   7        .700000E+01      0.

V2, IN        =    .750000E+01
W2, IN        =   0.

NSEL    =  0

IPROP =    0   0

RHO, LB-SFC**2/IN**4 =     .259000E-03    .259000E-03

WT, IN        =    .400000E+01

LAYER NUMBER              1
 H, IN              =     .880000E-01
 WP, IN             =     .400000E+01

 NSSC          =  3
   I              STRNA(L,I)      STRSO(L,I), LB/IN**2
   1             .550000E-02           .580000E+05
   2             .810000E-02           .730000E+05
   3             .100000E+00           .750000E+05

LAYER NUMBER              2
 H, IN              =     .970000E+00
 WP, IN             =     .720000E-01

 NSSC          =  3
   I              STRNA(L,I)      STRSO(L,I), LB/IN**2
   1             .550000E-02           .580000E+05
   2             .810000E-02           .730000E+05
   3             .100000E+00           .750000E+05

DELTIM, SEC   =    0.
TSTOP, SEC    =    .300000E-02
PRINT         =    .200000E+02
```

Figure 83. (Continued)

```
                                        D E P R O B

DELTIM, SEC =      .446026E-05        TOTAL MASS OF BEAM,   LB-SEC**2/IN     =      .764796E-03
TSTOP,  SEC =      .300000E-02

THE STRUCTURE IS NOT CIRCULAR IN SHAPE,
CLAMPED AT COORDINATES, V,W =                -.750000E+01  0.
AND SYMMETRIC IN THE SPANWISE DIRECTION

MATERIAL PROPERTIES

      LAYER     NUMBER OF      DENSITY
      NUMBER     FLANGES    LB-SEC**2/IN**4
        1      .600000E+01   .259000E-03
        2      .400000E+01   .259000E-03
        3      .600000E+01   .259000E-03

    LAYER  1
      THICKNESS, IN          .527300E-01   .527300E-01   .527300E-01   .527300E-01   .527300E-01
                             .527300E-01   .527300E-01   .527300E-01
      WIDTH, IN              .400000E+01   .400000E+01   .400000E+01   .400000E+01   .400000E+01
                             .400000E+01   .400000E+01   .400000E+01

    LAYER  2
      THICKNESS, IN          .352700E-01   .352700E-01   .352700E-01   .352700E-01   .352700E-01
                             .352700E-01   .352700E-01   .352700E-01
      WIDTH, IN              .400000E+01   .400000E+01   .400000E+01   .400000E+01   .400000E+01
                             .400000E+01   .400000E+01   .400000E+01

    LAYER  3
      THICKNESS, IN          .970000E+00   .970000E+00   .970000E+00   .970000E+00   .970000E+00
                             .970000E+00   .970000E+00   .970000E+00
      WIDTH, IN              .720000E-01   .720000E-01   .720000E-01   .720000E-01   .720000E-01
                             .720000E-01   .720000E-01   .720000E-01

    WIDTH FOR PRESSURE, IN   .400000E+01

    LAYER      AREA RATIOS OF SUBFLANGES
      1        .452918     .545019     .002064
      2        .452918     .545019     .002064
      3        .452918     .545019     .002064
```

Figure 83. (Continued)

FLANGE	ZETA				
1	-.127499E+00	-.127499E+00	-.127499E+00	-.127499E+00	-.127499E+00
	-.127499E+00	-.127499E+00	-.127499E+00		
2	-.118586E+00	-.118586E+00	-.118586E+00	-.118586E+00	-.118586E+00
	-.118586E+00	-.118586E+00	-.118586E+00		
3	-.109673E+00	-.109673E+00	-.109673E+00	-.109673E+00	-.109673E+00
	-.109673E+00	-.109673E+00	-.109673E+00		
4	-.100760E+00	-.100760E+00	-.100760E+00	-.100760E+00	-.100760E+00
	-.100760E+00	-.100760E+00	-.100760E+00		
5	-.918470E-01	-.918470E-01	-.918470E-01	-.918470E-01	-.918470E-01
	-.918470E-01	-.918470E-01	-.918470E-01		
6	-.829340E-01	-.829340E-01	-.829340E-01	-.829340E-01	-.829340E-01
	-.829340E-01	-.829340E-01	-.829340E-01		
7	-.748765E-01	-.748765E-01	-.748765E-01	-.748765E-01	-.748765E-01
	-.748765E-01	-.748765E-01	-.748765E-01		
8	-.657698E-01	-.657698E-01	-.657698E-01	-.657698E-01	-.657698E-01
	-.657698E-01	-.657698E-01	-.657698E-01		
9	-.566631E-01	-.566631E-01	-.566631E-01	-.566631E-01	-.566631E-01
	-.566631E-01	-.566631E-01	-.566631E-01		
10	-.475564E-01	-.475564E-01	-.475564E-01	-.475564E-01	-.475564E-01
	-.475564E-01	-.475564E-01	-.475564E-01		
11	.315187E-01	.315187E-01	.315187E-01	.315187E-01	.315187E-01
	.315187E-01	.315187E-01	.315187E-01		
12	.195479E+00	.195479E+00	.195479E+00	.195479E+00	.195479E+00
	.195479E+00	.195479E+00	.195479E+00		
13	.359439E+00	.359439E+00	.359439E+00	.359439E+00	.359439E+00
	.359439E+00	.359439E+00	.359439E+00		
14	.523399E+00	.523399E+00	.523399E+00	.523399E+00	.523399E+00
	.523399E+00	.523399E+00	.523399E+00		
15	.687358E+00	.687358E+00	.687358E+00	.687358E+00	.687358E+00
	.687358E+00	.687358E+00	.687358E+00		
16	.851318E+00	.851318E+00	.851318E+00	.851318E+00	.851318E+00
	.851318E+00	.851318E+00	.851318E+00		

Figure 83. (Continued)

MATERIAL PROPERTIES IN COMPRESSION

LAYER NUMBER	STRS-STRN SEGMENT	BREAK POINT STRESS	BREAK POINT STRAIN	STRESS-STRAIN SLOPE
1	1	.580000E+05	.550000E-02	.105455E+08
	2	.730000E+05	.810000E-02	.576923E+07
	3	.750000E+05	.100000E+00	.217628E+05
2	1	.580000E+05	.550000E-02	.105455E+08
	2	.730000E+05	.810000E-02	.576923E+07
	3	.750000E+05	.100000E+00	.217628E+05
3	1	.580000E+05	.550000E-02	.105455E+08
	2	.730000E+05	.810000E-02	.576923E+07
	3	.750000E+05	.100000E+00	.217628E+05

MATERIAL PROPERTIES IN TENSION

LAYER NUMBER	STRS-STRN SEGMENT	BREAK POINT STRESS	BREAK POINT STRAIN	STRESS-STRAIN SLOPE
1	1	.580000E+05	.550000E-02	.105455E+08
	2	.730000E+05	.810000E-02	.576923E+07
	3	.750000E+05	.100000E+00	.217628E+05
2	1	.580000E+05	.550000E-02	.105455E+08
	2	.730000E+05	.810000E-02	.576923E+07
	3	.750000E+05	.100000E+00	.217628E+05
3	1	.580000E+05	.550000E-02	.105455E+08
	2	.730000E+05	.810000E-02	.576923E+07
	3	.750000E+05	.100000E+00	.217628E+05

STRUCTURAL RESPONSE - ELASTIC ONLY

Figure 83. (Concluded)

```
AIRCRAFT ALTITUDE (ALT), FT                          .5000000E+04
AIRCRAFT VELOCITY (VEL), FT/SEC                      .9350000E+03
WEAPON YIELD (WKT), KT                               .1000000E+02
HEIGHT OF GROUND (HG), FT                            .4950000E+04
AIRCRAFT ANGLE OF ATTACK (ALFAA), RAD                .1000000E+00
HORIZONTAL TAIL INCIDENCE (HTINC), RAD              -.1000000E+00

BLAST MODEL USED - REFRA TAPE
  GROUND REFLECTION INCLUDED

ITERATION RUN
  ITERATION RESTRICTED TO CONSTANT ALTITUDE
  NO DAMAGE LEVEL, PROBABILITY OF EXCEEDING  .500

STRUCTURAL ELEMENT  1

METAL STRINGER OR LONGERON ON
HORIZONTAL TAIL
UPPER SURFACE

INTERNAL PRESSURIZATION =  0.          PSI

ORIENTATION 22          XOSRO =  0.                     YOSRO =  -.89638E+00

RANGE =   .26000E+04 FEET                                  ZOSRO =  -.44329E+00

TRIAL NUMBER  1

POINT INTERCEPTED BY MACH SHOCK

COMPATIBILITY CHECK ON HEIGHT OF BURST
  HEIGHT OF BURST, FT                                 =    .120255E+04
  HEIGHT OF BURST ASSOCIATED WITH REFRA TAPE, FT =    .120255E+04
```

Figure 84. Example Output for Stringer on Horizontal Tail

J= 0 TIME, SEC = 0.
STRAIN AT EDGE 1, INNER AND OUTER SURFACES = .710543E-14 .710543E-14 1

I	V, IN	W, IN	INTERNAL FORCE, LB	INTERNAL MOMENT, LB-IN	STRAIN, INNER SURFACE
1	-.65000000E+01	0.	.316085E-07	.338465E-22	.710543E-14
2	-.55000000E+01	0.	.893376E-36	0.	0.
3	-.45000000E+01	0.	0.	0.	0.
4	-.35000000E+01	0.	0.	0.	0.
5	-.25000000E+01	0.	0.	0.	0.
6	-.15000000E+01	0.	0.	0.	0.
7	-.50000000E+00	0.	0.	0.	0.

I	V-ACCELERATION IN/SEC**2	W-ACCELERATION IN/SEC**2	PRESSURE LB/IN**2	NET DISPLACEMENT INCHES
1	-.28930505E-03	.41134617E+06	.11235567E+02	0.
2	-.81768610E-32	.41134617E+06	.11235567E+02	0.
3	0.	.41134617E+06	.11235567E+02	0.
4	0.	.41134617E+06	.11235567E+02	0.
5	0.	.41134617E+06	.11235567E+02	0.
6	0.	.41134617E+06	.11235567E+02	0.
7	0.	.41134617E+06	.11235567E+02	0.

STRAIN, OUTER SURFACE	YIELD
.710543E-14	
0.	
0.	
0.	
0.	
0.	
0.	

Figure 84. (Continued)

J= 480 TIME, SEC = .214092E-02
STRAIN AT EDGE 1, INNER AND OUTER SURFACES = -.529892E-02 .824376E-03 2

I	V, IN	W, IN	INTERNAL FORCE, LB	INTERNAL MOMENT, LB-IN	STRAIN, INNER SURFACE
1	-.64999780E+01	.27835580E-02	.121558E+03	-.977207E+03	-.372206E-02
2	-.54999774E+01	.10121409E-01	.122367E+03	-.547179E+03	-.197921E-02
3	-.44999967E+01	.19816530E-01	.123174E+03	-.137224E+03	-.475577E-03
4	-.35000219E+01	.30102810E-01	.123249E+03	.232074E+03	.878795E-03
5	-.25000374E+01	.39389315E-01	.122777E+03	.541870E+03	.201485E-02
6	-.15000342E+01	.46341414E-01	.122074E+03	.757013E+03	.280376E-02
7	-.50001364E+00	.50032198E-01	.121546E+03	.856690E+03	.316926E-02

I	V-ACCELERATION IN/SEC**2	W-ACCELERATION IN/SEC**2	PRESSURE LB/IN**2	NET DISPLACEMENT INCHES
1	-.12271481E+04	-.13273588E+05	.10717836E+02	.27836450E-02
2	-.34744284E+04	.21130795E+06	.10717836E+02	.10121434E-01
3	-.16233580E+04	.20936382E+05	.10717836E+02	.19816531E-01
4	.28817076E+03	-.15332124E+06	.10717836E+02	.30102818E-01
5	.30351914E+04	-.47651021E+06	.10717836E+02	.39389332E-01
6	.34258773E+04	-.66802587E+06	.10717836E+02	.46341426E-01
7	.11142868E+04	-.52399997E+06	.10717836E+02	.50032200E-01

STRAIN, OUTER SURFACE	YIELD
.588806E-03	
.328150E-03	
.103071E-03	
-.998198E-04	
-.270115E-03	
-.388427E-03	
-.443255E-03	

Figure 84. (Continued)

J= 673 TIME, SEC = .300175E-02
STRAIN AT EDGE 1, INNER AND OUTER SURFACES = -.165957E-02 .250108E-03 2

I	V, IN	W, IN	INTERNAL FORCE, LB	INTERNAL MOMENT, LB-IN	STRAIN, INNER SURFACE
1	-.64999990E+01	.81833694E-03	.636022E+01	-.236139E+03	-.940138E-03
2	-.54999996E+01	.28111435E-02	.628716E+01	-.806169E+02	-.294273E-03
3	-.45000010E+01	.51512536E-02	.610781E+01	.291950E+02	.108429E-03
4	-.35000021E+01	.73655893E-02	.594840E+01	.882025E+02	.324826E-03
5	-.25000024E+01	.91999416E-02	.596562E+01	.121102E+03	.445508E-03
6	-.15000019E+01	.10512577E-01	.614547E+01	.142945E+03	.525662E-03
7	-.50000072E+00	.11209392E-01	.634425E+01	.161746E+03	.594646E-03

I	V-ACCELERATION IN/SEC**2	W-ACCELERATION IN/SEC**2	PRESSURE LB/IN**2	NET DISPLACEMENT INCHES
1	-.12356825E+04	-.17229176E+06	.10594553E+02	.81833751E-03
2	-.19971681E+04	-.30479357E+05	.10594553E+02	.28111435E-02
3	-.11862413E+04	-.77131373E+05	.10594553E+02	.51512537E-02
4	.16020081E+02	.14889668E+06	.10594553E+02	.73655896E-02
5	.13257782E+04	.28665835E+06	.10594553E+02	.91999420E-02
6	.15722237E+04	.35999656E+06	.10594553E+02	.10512577E-01
7	.73611234E+03	.21576015E+06	.10594553E+02	.11209392E-01

NORMAL DEPROB STOP CONDITION AT T, SEC = .300175E-02

STRAIN, OUTER SURFACE	YIELD
.142439E-03	
.456741E-04	
-.146810E-04	
-.471084E-04	
-.651571E-04	
-.771125E-04	
-.874077E-04	

Figure 84. (Continued)

```
DEPROB -
RESULTS OF RANGE ITERATION    1

LINK NUMBER        =    1
LAYER NUMBER       =    3
FLANGE NUMBER      =    6
TIME (SEC)         =      .66011782E-03
STRAIN (IN/IN)     =     -.59436535E-02
STRESS (PSI)       =     -.62678528E+05

CRIT(1)            =      .10806643E+0

     YIELD STRAIN FIRST EXCEEDED AT TIME =    .0005977

     NET CP TIME FOR RESPONSE, SEC =      6.120
```

Figure 84. (Continued)

```
STRUCTURAL ELEMENT  1

ORIENTATION 22            XOSRO =  0.                     YOSRO =  -.89638E+00

RANGE =    .26000E+04 FEET                                     ZOSRO =  -.44329E+00

TRIAL NUMBER  1

POINT INTERCEPTED BY MACH SHOCK

VECTOR FROM AIRCRAFT TO BURST POINT AT SHOCK ARRIVAL
X =  0.           FEET       Y =   .233059E+04 FEET       Z =   .115255E+04 FEET

VECTOR FROM AIRCRAFT TO BURST POINT AT BURST TIME
X =   .126889E+04 FEET       Y =   .233059E+04 FEET       Z =   .115255E+04 FEET

SHOCK ARRIVAL TIME =    .135710E+01 SEC

SHOCK OVERPRESSURE =    .886254E+01 PSI



ORIENTATION 22            XOSRO =  0.                     YOSRO =  -.90908E+00

RANGE =    .27665E+04 FEET                                     ZOSRO =  -.41662E+00

TRIAL NUMBER  2

POINT INTERCEPTED BY MACH SHOCK

COMPATIBILITY CHECK ON HEIGHT OF BURST
  HEIGHT OF BURST, FT                                 =    .120255E+04
  HEIGHT OF BURST ASSOCIATED WITH REFRA TAPE, FT =    .120255E+04
```

Figure 84. (Continued)

```
DEPROB -
RESULTS OF RANGE ITERATION   2

LINK NUMBER       =   1
LAYER NUMBER      =   3
FLANGE NUMBER     =   6
TIME (SEC)        =     .68687935E-03
STRAIN (IN/IN)    =    -.53308171E-02
STRESS (PSI)      =    -.56215889E+05

CRIT(1)           =     .96923947E+00

    STRUCTURE REMAINED ELASTIC

    NET CP TIME FOR RESPONSE, SEC =       6.121
```

Figure 84. (Continued)

```
STRUCTURAL ELEMENT  1

ORIENTATION 22          XOSRO =  0.                    YOSRO =  -.90908E+00

RANGE =   .27665E+04 FEET                                     ZOSRO =  -.41662E+00

TRIAL NUMBER  2

POINT INTERCEPTED BY MACH SHOCK

VECTOR FROM AIRCRAFT TO BURST POINT AT SHOCK ARRIVAL
X =  0.          FEET       Y =   .251495E+04 FEET       Z =   .115255E+04 FEET

VECTOR FROM AIRCRAFT TO BURST POINT AT BURST TIME
X =   .139026E+04 FEET      Y =   .251495E+04 FEET       Z =   .115255E+04 FEET

SHOCK ARRIVAL TIME =   .148691E+01 SEC

SHOCK OVERPRESSURE =   .843562E+01 PSI
```

Figure 84. (Continued)

```
END OF ITERATION
ESTIMATED RANGE, FT = .271867E+04

STRUCTURAL ELEMENT  1

ORIENTATION 22          XOSRO =  0.                    YOSRO =  -.90569E+00
                                                              ZOSRO =  -.42394E+00
RANGE =    .27187E+04 FEET

POINT INTERCEPTED BY MACH SHOCK

VECTOR FROM AIRCRAFT TO BURST POINT AT SHOCK ARRIVAL
X =  0.            FEET        Y =   .246228E+04 FEET       Z =   .115255E+04 FEET

VECTOR FROM AIRCRAFT TO BURST POINT AT BURST TIME
X =   .135537E+04 FEET         Y =   .246228E+04 FEET       Z =   .115255E+04 FEET

SHOCK ARRIVAL TIME =   .144959E+01 SEC

SHOCK OVERPRESSURE =   .849496E+01 PSI
```

Figure 84. (Continued)

SUMMARY OF NOVA RESULTS
NOVA-2 SAMPLE PROBLEM - STRINGER ON HORIZONTAL TAIL

ORIGINAL ORIENTATION NUMBER	STRUCTURAL ELEMENT NUMBER	VECTOR FROM AIRCRAFT TO BURST POINT AT SHOCK ARRIVAL X (FT)	Y (FT)	Z (FT)	VECTOR FROM AIRCRAFT TO BURST POINT AT BURST TIME X (FT)	Y (FT)	Z (FT)
22	1	0.0	2462.3	1152.6	1355.4	2462.3	1152.6

TABLE OF THE CRITICAL ELEMENT FOR EACH ORIENTATION

ORIGINAL ORIENTATION NUMBER	CRITICAL ELEMENT NUMBER	RANGE (FT)	SHOCK OVERPRESSURE (PSI)	SHOCK ARRIVAL TIME (SEC)
22	1	2718.7	8.495	1.450

Figure 84. (Concluded)

SUMMARY OF NOVA RESULTS
NOVA-2 SAMPLE PROBLEM - STRINGER ON HORIZONTAL TAIL

ORIGINAL ORIENTATION NUMBER	STRUCTURAL ELEMENT NUMBER	VECTOR FROM AIRCRAFT TO BURST POINT AT SHOCK ARRIVAL X (FT)	Y (FT)	Z (FT)	VECTOR FROM AIRCRAFT TO BURST POINT AT BURST TIME X (FT)	Y (FT)	Z (FT)
22	1	0.0	2687.4	1152.6	1492.5	2687.4	1152.6

TABLE OF THE CRITICAL ELEMENT FOR EACH ORIENTATION

ORIGINAL ORIENTATION NUMBER	CRITICAL ELEMENT NUMBER	RANGE (FT)	SHOCK OVERPRESSURE (PSI)	SHOCK ARRIVAL TIME (SEC)
22	1	2924.1	10.594	1.596

Figure 85. Final Output for Example Problem Number 3

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